

**OBSERVATIONS ON THE POPULATION CHARACTERISTICS
OF THE CORBICULID CLAM *VILLORITA CYPRINOIDES* (GRAY)
IN THE CHITRAPUZHA PORTION OF THE VEMBANAD LAKE**

DISSERTATION SUBMITTED BY

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C E R T I F I C A T E

This is to certify that this dissertation is a bonafide record of work carried out by **Shri. JOE K. KIZHAKUDAN**, under my supervision and that no part thereof has been presented before for any other degree.



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PREFACE

Fishery products, being excellent animal protein supplements, can be easily availed by all sections of people and have served to meet the nutritional requirements of population since time immemorial. However, the geometric expansion of the global population and the slower growth rate of the world's food production leaves a large gap between the nutritional demands and supply, especially in the developing and under-developed countries. Pressed by growing needs, man is forever venturing forth to explore and exploit all available natural resources, through techniques old and new, and often creates a situation wherein irrational exploitation tends to deplete their availability to an alarming level. Aquatic resources are no exception to this case. Several stocks of finfish and shellfish in the presently exploited areas have reached the maximum sustainable levels and there is no scope to step up the production further. To compensate this inadequacy, man has now taken up the task of propagating aquaculture with added impetus.

The contribution of fishery products to the total food production plateaued during the mid - 1970's at 16% and decreased substantially in the early 1980's only to surface again towards the end of the same decade due to a sudden expansion in aquaculture production. The chief driving force behind this expansion is the robust demand for sea food products in international markets. Out of a reported world aquaculture production of 15.6 million tonnes in 1991 (Rhodes, 1993), finfish contributed to 55%, molluscs, 19% and crustaceans formed 5%. Though finfish and crustaceans

dominate the international markets, molluscs have gained considerable importance as good sources of animal protein in European countries, the United States and countries of south-east Asia.

India, with a production of 1.01 million tonnes in 1990, is ranked third among the major aquaculture producing countries of the world. However, the culture of molluscs on commercial lines is not presently practised in the country. This is because the demand is limited to a small segment of the population, usually confined to the coastal areas. Wild harvest of the natural stocks of mussels, clams and oysters are at present adequate to meet the limited demand. Although production oriented culture technologies for several candidate species have been developed in the recent past, commercialisation is yet to take off because there is a general lack of awareness about the nutritive value of molluscs. They are not conventionally eaten and hence there is a hesitation on the part of prospective entrepreneurs to venture into this less familiar area of mollusc culture.

The world aquaculture production of clams was estimated at 5 lakh tonnes in 1990 (FAO, 1992). The annual production of clams from the harvest of natural resources from India was estimated at 45,412 t (Narasimham, 1992). Among the exploited bivalve resources of India, clams are, by far, the most widely distributed and abundant; they support sustenance fisheries in the estuaries and backwaters of Kerala, Karnataka, Goa, Tamilnadu and Andhra Pradesh.

The black clam, Villorita cyprinoides, tops the clam production, forming 67% (29,077 t) of the total estimated annual production. This species forms a fishery along the west coast in Goa, Karnataka and Kerala in brackish water habitat. Major production centres in Kerala are the Vembanad and Ashtamudi lakes. The black clam meat is consumed at several coastal places in Kerala. The shells of this clam dominate the sub-soil deposits of the Vembanad Lake (41,000-70,000 t/year; Achari, 1988b) and contribute substantially to the total shell deposit landings (1,76,610 t/year : Narasimham, 1991). The shells of this clam are used in lime based industries. In view of their near sedentary habits clams are particularly vulnerable to over-exploitation; they are admirably suited for on-bottom farming.

Keeping in view the importance of V. cyprinoides in the rural economy of Kerala water bodies, this study on various ecological and biological aspects of V. cyprinoides was undertaken so that the information collected would be useful in the management of this valuable resource. The study was carried out on the following aspects:

1. Ecology, comprising hydrographical and physico-chemical parameters,
2. Distribution of clams and their abundance,
3. Biology of clams, and
4. Aspects of physiology

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Chapter I

I - INTRODUCTION

The distribution and abundance of natural resources are governed by several factors which may be physico-chemical, biological or anthropogenic. One of the most important preliminary aspects which ultimately determines the very existence of the resources is the ecology of the environment in which it thrives.

The estuarine ecosystem, which is the most dynamic of aquatic ecosystems, reveals the complexity of the operating forces of both marine and freshwater origin, induced mainly by tidal incursion, current patterns and the magnitude of freshwater discharge at different periods and seasons (Ketchum, 1951; Preddy, 1954; Cameron and Pritchard, 1963). Emery and Stevenson (1957) reported that the concentration of nutrients is relatively high in estuarine systems as a result of close proximity to land drainage. Detailed reports on the ecology of Cochin backwaters have been given by several authors (Ramamritham and Jayaraman, 1963; George and Kartha, 1963; Qasim et al., 1968; Sankaranarayanan and Qasim, 1969; Qasim and Gopinathan, 1969; Nair and Tranter, 1971). In a study of the Cochin backwaters, Qasim et al. (1969) recorded high primary productivity and high dissolved oxygen during premonsoon and monsoon months. Haridas et al. (1973) gave an account of the seasonal variations in salinity in this ecosystem.

The hydrographical conditions of the estuarine system depend on the interaction of sea and freshwater, the former dominating in summer

and the latter during the monsoon months. There is thus, a seasonal variation in water parameters. The quantity of freshwater discharged into the estuary, during the rainy season, through rivers and land run-off is so high that tidal influence becomes almost negligible during this period.

Ellis (1970), recognising the difficulties of delimiting the ecosystem, used indices of dispersion, density, biomass and respiration rate to suggest objectively, which species merit autoecological study. Earlier, Jones (1950) put forward a scheme of classification of animal associations based on environmental factors like depth, salinity and nature of substratum. Estuaries provide an environmental gradient in physiological stress for organisms of marine origin (Norse and Estevez, 1977).

Amongst all the physical environmental factors, the nature of the substratum has the greatest influence on the distribution and abundance of benthic populations (Sanders, 1959; Pillai, 1977). March and Stinemetz (1983) reported that invertebrate distribution reflects substrate size and stability and the presence of organic matter. Buchanan and Kaine (1971) have stated the correlation between the animals and the granulometry of the sediment to be the key to benthic ecology. The physical property of the deposit exerts an appreciable effect on the animal, from a biological point of view, for food relationships. The effects of deposit grade upon the fauna can be elucidated by observations and experiments on individual species, as was done by Ekman (1947) and Yonge (1937, 1946). Wilson's (1952) conclusions regarding the role of physical and chemical properties

of the deposit on larval settlement are supported by Thorson (1951) and Knight - Jones (1955). Webb (1969) commented on the effect of porosity and permeability of soil on animal distribution. The number of ecological niches available in a substratum has been shown to depend on the median particle diameter of the substratum .

Several works carried out show that different behavioural patterns dictate different species of animals to seek optimal conditions on or in different substrates (Sanders, 1956; 1958; 1959; 1960; Williams, 1958; Kohn, 1959; Weiser, 1959; 1960). The physiological and morphological organisation peculiar to each species apparently determines the range of deposits upon which it will survive, or where applicable, settle (Harvey, 1950), Christies (1978) gives an account of the relation between soil texture, species richness and volume of soil sampled by means of a grab. Over the years a lot of work has been documented on the ecology of clam beds and the distribution and abundance of clams in relation to the physical and chemical characteristics of their substratum. Bourgoutzani and Zenettos (1983) concluded that the distribution of molluscan fauna is related to sediment type, with coarser sediments showing greater species diversity. Gottfried & Osborne (1982), in a study on the abundance of the Corbiculid clam, Corbicula manilensis, reported a greater density of clams in regions having clear fine sand, the least density occurring in silty organic sediments near head waters. Qi (1985) recorded a high abundance of C. fluminea in sediments having a high proportion of particles of diameter above 0.4 mm. Belanger et al. (1985) reported that C. fluminea showed a preference for fine sand (0.25 - 0.7 mm particle size), organically enriched fine sand (0.25 - 0.7 mm particle size) and coarse

sand (2.5 - 4.5 mm particle size). An earlier report (Anon, 1983) attributed large shifts in sediment structure and wave activity to be the major factors influencing differential distribution of molluscs. Leef et al. (1990) reported the dominance of C. fluminea in gravel beds. Several other workers have documented similar correlation between sediment type and distribution and abundance of clams, and other benthos (Chari et al., 1985; Henry and Simao, 1985, 1986; Richter, 1985; Mc Ardle and Blackwell, 1989; Nakao et al., 1989; Qingwei et al., 1990).

The ecology of clam beds in India have been studied by several authors for Anadara granosa (Narasimham et al., 1984) Meretrix casta (Parulekar et al., 1973; 1984; Harkantra, 1975a,b, Rao et al., 1980, Sreenivasan, 1983a,b; 1985), Paphia malabarica (Parulekar et al., 1984) and Villorita cyprinoides (Parulekar et al., 1984; Rao et al., 1989). Reports on the habitat preferences, density, biomass and distribution are available for A. granosa (Radhakrishna and Ganapathi, 1968), M. ovum (Desai, 1971; Kurian, 1972), Donax cuneatus (Victor and Subramonian, 1988), D. incarnatus (Ansell et al., 1972; 1973) and V. cyprinoides (Joseph and Joseph, 1988).

The effects of factors like depth, temperature, salinity and food availability on the distribution and abundance of benthos have also been documented. Dreier and Tranquilli (1981) reported that the population density of Corbicula varies inversely with depth. John and Fernandes (1989) reported that V. cyprinoides prefers an estuarine sediment and its burrowing behaviour is affected by salinity, temperature and alkalinity and is also dependent on the concentrations of zinc and copper in the sediment.

Detailed studies on the population dynamics of an animal is vital for evolving suitable management measures for rational exploitation of its resources. Studies on the population dynamics of several clams and bottom dwellers have been documented by many authors (Coe, 1956; Crisp, 1971; McCall, 1977; Josefson, 1982; Stites, 1987; Narasimham, 1988; Defeo et al., 1992). Coe (1956), McCall (1977) and Josefson (1981) have reported that the extremities of temperature and salinity exhibited by shallow water bottoms regulate the population dynamics of bivalves. Scheltema (1986), Butman (1987) and Woodin (1991) state that settlement of planktonic larvae of benthic invertebrates is undoubtedly determined by a combination of active larval behaviour and hydrodynamic processes that distribute larvae as if they are passive particles. The differential selectivity of substratum by larvae has been studied by several workers (Meadows and Campbell, 1972; Gray, 1974; Crips, 1984; Woodin, 1986; Butman et al., 1988; Grassle and Butman, 1989; Bachelet et al., 1992; Grassle et al., 1992). Sediment selectivity by settling larvae of infaunal organisms does not preclude post-settlement phenomenon from further restricting adult distribution (Muus, 1973; Wilson, 1980; Luckenbach, 1984; Woodin, 1985; Peterson, 1986; Watzin, 1986). Settlement in fact, may be random, but rapidly followed by mortality in unpreferable areas Connell and Slatyer (1977), Paine (1979), Keough and Downes (1982), Summerson and Peterson (1984), Peterson (1986) and Fairweather (1988) have given several accounts of post-settlement events that affect mortality. Differential post-settlement mortality may have been an important selective agent that led to the evolution of larval preferences for specific micro habitats (Doyle, 1974; Young and Chia, 1984).

Recruitment of benthos has been found to vary in space and time (Thorson, 1950; Loosanoff, 1964; Ebert, 1982; Caffey, 1985; Gaines et al., 1985) and fluctuations in recruitment can have important consequences on population and community structure (Yoshioka, 1982; Underwood and Denley, 1984). Roughgarden et al. (1985) noted that variable recruitment can induce oscillations in single species population models.

Differences in larval production led to significant annual fluctuations in the size specific reproductive output of individuals from different populations of the clam, Corbicula fluminalis (Foe and Knight, 1981). A complex interplay of intrinsic and extrinsic factors have been suggested to play a role in determining the mechanism of reproduction chronology (Scheibling, 1981).

In India, several studies have been conducted on aspects of biology of clams; mention is made on A. granosa (Patel and Patel, 1964; 1974; Narasimham, 1969; 1983; 1985; 1985a, 1988), A. rhombea (Patel and Patel, 1964; 1974, Natarajan and John, 1983; Narasimham, 1988), M. meretrix (Hornell, 1922; Rai, 1932; Jaybal & Kalyani, 1986), M. casta (Hornell, 1922; Panikkar and Aiyar, 1937; Abraham, 1953, Durve and Dharmaraja, 1965, 1969, 1972. Seshappa, 1971; Parulekar et al., 1973, 1984, Durve and George, 1973; Salih, 1974, Harkantra, 1975, Mohan et al., 1983; Joseph and Joseph, 1988; Rao et al., 1988) Katelysia opima (Rao, 1952, Nagabushanam and Mane, 1975, 1983; Mane, 1981; Kalyanasundaram and Kasinathan, 1983; Sreenivasan, 1985; Joseph and Joseph, 1988), Paphia sp. (Winckworth, 1931; Krishnakumari and Rao, 1974;

Nagabushanam and Dhamne, 1977a,b; Mane and Nagabushanam, 1979; Rao, 1988) and V. cyprinoides (Nair, 1975; Chatterji et al., 1984; Achari 1988; Joseph and Joseph, 1988).

Estuarine and intertidal organisms which are regularly subjected to variations in many environmental parameters, often experience changes in temperature, water turbidity, wave action, degree of exposure, partial pressure of oxygen, osmotic pressure and ionic content of water. The ability of these organisms to adapt resistance to stress likely to be experienced at particular habitats is a well established fact (Day, 1967; Newell, 1970). One of the most important stress including factors controlling the distribution of estuarine species is salinity (Emery et al., 1957). The survival and behaviour of oysters in low salinities has been studied by Amemiya (1928); Hopkins (1936); Ingle and Dawson (1950) and Loosanoff (1934, 1950, 1952). Chalney (1958) studied the survival of juvenile bivalves in low salinity conditions. Motwani (1956) worked out the adaptations to salinity fluctuations in the mussel, Mytilus edulis. Ranade and Kulkarni (1972) found that salinity plays an important part in the opening and closing of the valves. Adaptations to environmental variability are associated with differences in physiological mechanisms among brackish water bivalves (Deaton, 1992). According to the author, brackishwater bivalves with similar salinity ranges seem to possess broadly similar mechanisms and capabilities for the maintenance of water balance. The processes which underly osmoregulation include active ion transport and intracellular amino acid metabolism (Lange, 1968; Davenport, 1972; Vernberg and Vernberg, 1972; Prosser, 1973; Gilles, 1975).

In the present study investigations were carried out on various population characteristics of the black clam Villorita cyprinoides (Gray), which occurs along the brackishwater bodies of the Malabar coast of peninsular India. This is a purely brackish water species, which cannot tolerate high salinities (Cheriyian, 1966). Records designate the clam to the following taxonomic classification:

Phylum	:	Mollusca
Class	:	Pelecypoda
Order	:	Eulamellibranchiata
Suborder	:	Heterodonta
Family	:	Corbiculidae
Sub-family	:	Corbiculinae
Genus	:	<u>Villorita</u> (Griffith and Pidgeon, 1833)
Species	:	<u>cyprinoides</u> (Gray, 1825)

The clam has a moderately large, thick, ovately triangular, inflated, oblique shell, swollen in the umbonal region and in the middle regions, the umbone lying near the anterior margin recurved inwards. The short anterior margin is evenly curved above, almost straight in the middle, rapidly curving backwards below and continued into a ventral border which curves upwards posteriorly to meet the posterior margin in an angular corner.

V. cyprinoides, which can tolerate very low salinities occurs in the upper reaches of estuaries and backwaters in Kerala. Hornell (1921), in an exhaustive study on the abundance and distribution of the common molluscs of India, reported that Villorita species was low in abundance along backwaters and occupied a habitat more distant from the sea. Rasalam and Sebastian (1976) reported only a marginal increase in the V. cyprinoides resource of the Vembanad Lake over the years. However, more recent studies (Kurup et al., 1989) have shown that there has been considerable increase in the resources of this clam along the lake so that, the niches earlier occupied by other clams (Meretrix sp.), are now likely to have been taken up by the black clam, which almost exclusively supports the clam fishery in these areas.

Traditional exploitation of especially the small sized clams (Achari, 1988, Appukuttan et al., 1988) and the growing evidence of the destruction of natural clam beds by man's activities like dredging, land reclamation and other engineering works (Nayar et al., 1984; Narasimham et al., 1986; Achari, 1988), makes it essential to possess a good knowledge of the ecology and biology of the animals concerned. It is hoped that the present study will throw some light on the biological and eco-physiological characteristics of V. cyprinoides.

Chapter II

II - MATERIAL AND METHODS

During the present investigation on the clam, *Villorita cyprinoides* (Gray) (Fig. 2) both field and laboratory studies were carried out based on collection of samples from a natural bed.

2.1 Area of Study

The site selected for the present study was a 12 km long stretch of the Chitrapuzha river joining the mainstream of the Vembanad Lake of Cochin barmouth. The Vembanad Lake, with its chain of shallow brackish water lagoons and swamps, is the largest lake on the west coast of India and lies parallel to the coast. Many fresh water rivers find their way to this lake. The area chosen lies between lat. N $10^{\circ} - 9^{\circ}55'$ and long. E $76^{\circ}15' - 76^{\circ}20'$ and exhibits considerable variations in different physico-chemical and biological characteristics. Six stations were fixed in the study area (Fig.1), taking into consideration the variability of different ecological parameters and accessibility for sampling. In each station, three substations were fixed in a transect, each separated from the other by 10 m. In the area of study, the depth varied from 0.6 to 4.5 m and the tidal amplitude was approximately 50 cm.

2.2 Sampling

Sampling was carried out at all the stations once during the second week of every month for a period of seven months (April 1993 to October

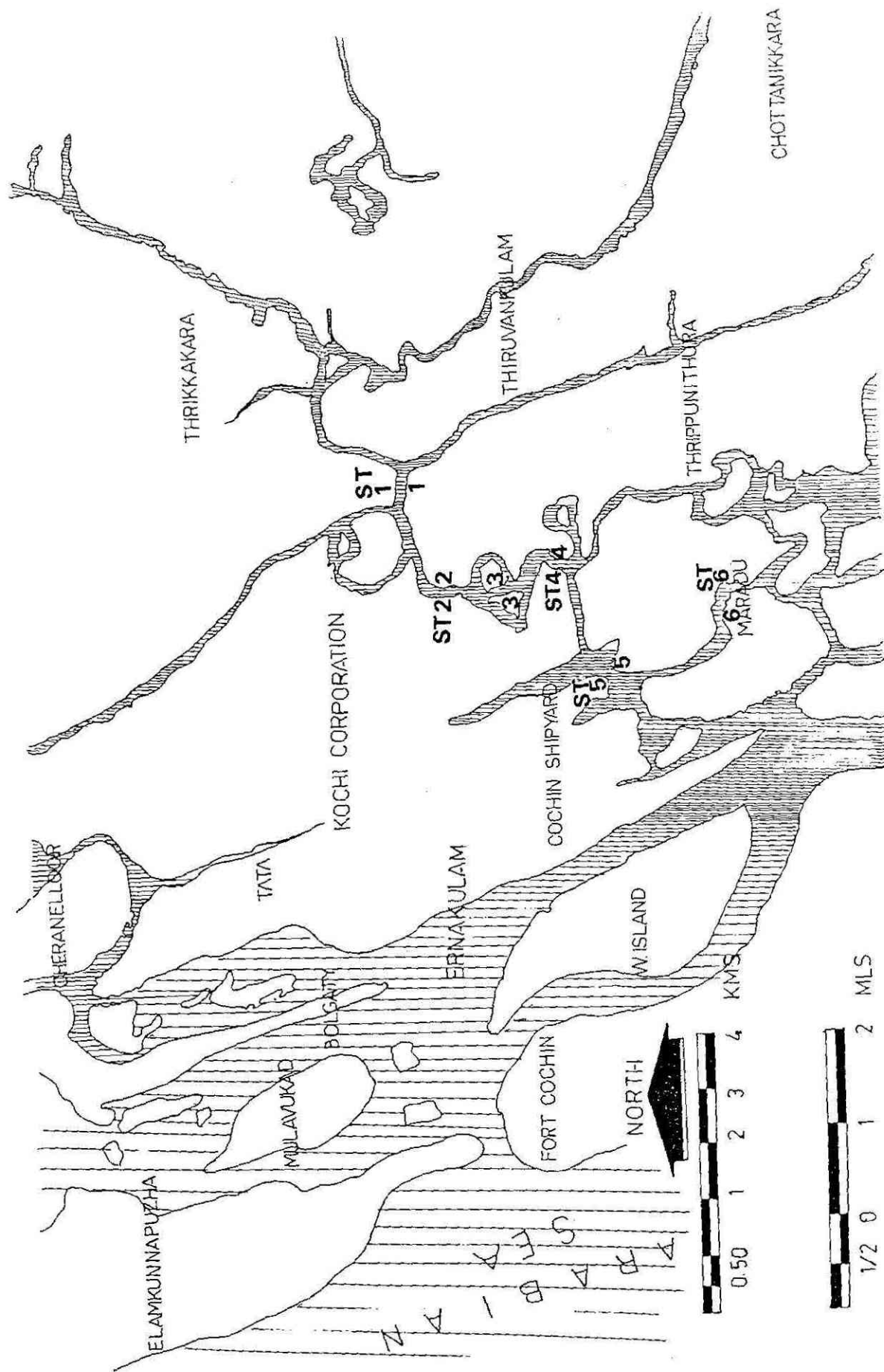


Fig.1 SITE OF STUDY

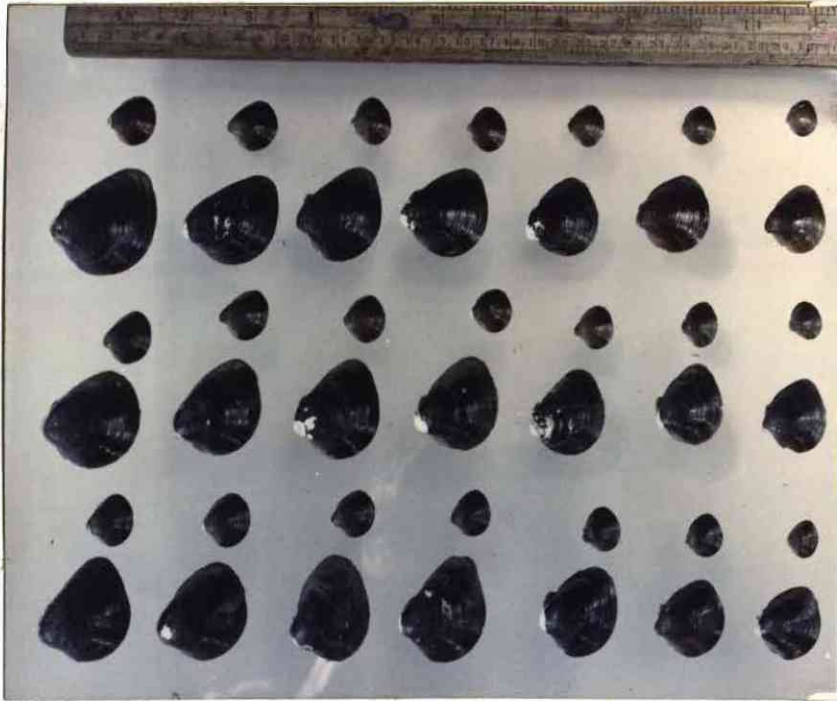


Fig. 1 Villorita cyprinoides from study area.



Fig. 2 V. cyprinoides from less saline conditions.



Fig. 2 V. cyprinoides : Sub-fossil shell valves.

1993). An expert diver and a 5 m long canoe (Fig. 4) were employed for the work. Water, sediment and biological samples were collected from each substation during all the sampling days; water depth was measured by using a rope tied to a lead sinker.

Apart from the above mentioned stations, Poothotta and Vechoor, where low salinity prevailed, were taken as reference stations for settlement studies taking into account the heavy spatfall that occurs in these areas. These stations were located further south of the barmouth, at a distance of 20-30 km from the study area.

2.3 Collection and Transportation of Samples

2.3.1 Biological Samples

Diving and hand-picking were found to be an effective method for clam collection than core or dredge sampling since operation of cores and dredges from a canoe with very little working space, especially at greater depths was found to be difficult. Moreover, dense clam beds offered resistance to these samples. A 0.25 sq.m. quadrat (Fig. 3) made of iron was used for quantitative sampling. It was lowered to the substation by means of a nylon rope and the clams along with the substrate inside the quadrat were collected upto a depth of 5 cm. It was observed that the clams do not burrow below 5 cm. The sediment was sieved for clams greater than 5 mm length and another sediment sample collected adjacent to the quadrat covering 0.04 sq.m.

PLATE II



FIG. IV Canoe used for sampling



FIG. V Canoe loaded with V. cyprinoides

PLATE III



FIG. VI Sampling materials : (a) 0.25 sq.m quadrat (b) Soil scoop (c) Oxygen/salinity bottles (d) Cassella bottom water sampler (e) Secchi disc.



FIG.VII Canoe with sampling materials

was sieved for spat of 1-5 mm. The clams collected were transported to the laboratory in enamel trays half filled with ambient water. The spat was preserved in 5% formalin.

2.3.2 Water Samples

Water overlying the sediment was collected using a Cassella bottom water sample and was transported to the laboratory in salinity bottles and oxygen bottles. For dissolved oxygen the water samples were carefully collected without entry of air bubbles and fixed with Winkler's solutions A and B, on board the canoe itself. Water temperature and transparency were measured at the site using an ordinary mercury thermometer and a secchi disc (Fig.

2.3.3 Sediment Samples

A separate sediment sample was collected at each substation within 1 m of the area from where biological samples were collected (vide: 2.3.1). This procedure was followed to ensure that the sediment was intact for textural analysis. The samples were packed in pre-labelled polythene bags and transported to the laboratory.

2.4 Analysis of Samples

2.4.1 Biological Samples

2.4.1.1 Measurement of Shell Dimensions

The following shell dimensions in the longest axis were measured, using a vernier calipers, to 0.1 mm accuracy:

- (i) Antero - posterior measurement (length) - APM
- (ii) Dorso-ventral measurement (height) - DVM
- (iii) Side to side distance in the broadest region when the valves were closed
- Depth

2.4.1.2 Measurement of Weights

All clams of greater than 20 mm in length were weighed individually to 0.01 mg accurately on a Mettler's weighing balance to obtain the following weights:

- (i) Shell-on weight (whole)
- (ii) Wet flesh weight (soft body)
- (iii) Dry flesh weight
- (iv) Weight of the two shell valves

Clams measuring less than 20 mm in length were weighed for shell-on weight (whole) only.

After taking the shell-on weight, the flesh was carefully removed with a stainless steel scalpel and the flesh weight and shell weight were noted.

The flesh was then dried to constant weight for 48 hrs in an oven pre-heated to 70°C, and the dry weights were recorded.

2.4.1.3 Preparation of Gonad Smear

Gonadial smears were prepared from animals measuring 20 mm to 50 mm in length from random samples collected each month. The classification of the maturity stages was done following the guidelines given by Narasimham (1988).

2.4.2 Water Samples

2.4.2.1 Estimation of Dissolved Oxygen

Estimation of dissolved oxygen was done by Winkler's titration method (Strickland and Parson, 1968). The water samples taken in 125 ml air-tight oxygen bottles were fixed with 1 ml each of Winkler's solution 'A' and 'B' at the site of collection. These were then brought to the laboratory where the precipitate in the bottles was dissolved in 2 ml of concentrated hydrochloric acid. After thorough mixing, 100 ml of this solution was titrated against standard sodium thiosulphate using starch as indicator. The observations were noted and the dissolved oxygen (in ml/l) was calculated.

2.4.2.2 Estimation of Salinity

Water salinity was estimated following the silver nitrate titration method as given by Mohr and Knudsen (Strickland and Parson, 1968); the water samples

collected in the salinity bottles were titrated against standard silver nitrate using potassium dichromate as indicator. The salinity of the water was calculated from the readings obtained.

2.4.3 Sediment Samples

The soil samples were spread on papers and dried before subjecting them to further analyses.

2.4.3.1 Texture Analysis

The International Pipette method, as described by Ganguly (1982), which is a modified methodology of seive pipette method of Krumbein and Pettijohn (1938) as quoted by Buchanan and Kain (1971), was followed for the analysis. This involves the dispersion and fractionation of dried soil samples after moistening. Known weight of soil sample was mixed with 30 ml, 6% H_2O_2 and heated intermittently till the evolution of CO_2 ceased. To this was added 100 ml water and 25 ml of 2N HCl; it was then filtered and washed through a filter paper (No.1) and washed with hot distilled water several times until free of Cl^- ions. The soil was then transferred to the sedimentation cylinders by washing with distilled water. To this 10 ml of 1 N NaOH was added and the solution was made upto 100 ml. The suspension was made by proper shaking. 10 ml of suspension was drawn twice, first for silt and clay and next for clay fraction alone (Fig. 8).

PLATE IV



FIG. VIII Soil analysis



FIG. IX Substrate specific spat settlement sampler (S-5)

The intervals of pipetting was based on atmospheric temperature. The particles were graded on the basis of the gradations specified as given below:

Nature of Particles	Particle size (mm)
Sand (coarse+fine)	2 - 0.02 (2 - 0.02 + 0.2 - 0.02)
Silt	0.02 - 0.002
Clay	0.002 - 0.0005

The ratios of sand, silt and clay were calculated from the weight percentages and the texture of the sediments was determined, based on the proportions of these particles (Shepard, 1954).

2.4.3.2 Estimation of Organic Carbon

Estimation of organic carbon was done, following the Walkley and Black method (wet oxidation technique), as approved by the International Society of Soil Sciences. The method estimates the percentage of carbon (excluding the carbonates) in the organic matter, which is approximately 77% of the total carbon in the soil. Hence, the value obtained is multiplied by the factor, $100/77$, to get the actual value. Assuming that soil organic matter contains 58% C, the percentage of organic carbon multiplied by 1.724 (ie. $100/58$), gives the percentage of organic matter in the soil sample (Wisemann and Bennette, 1940). The organic nitrogen in the soil is estimated approximately by dividing the organic matter value by 20.

2.5 Studies on Spat Settlement

A sampler was devised to study the settlement characteristics of the spat of V. cyprinoides. The frame work consisted of a wooden tray, divided into four equal chambers (25 x 25 cm each), supported on four legs (40 cm length). The walls of the chambers were covered with non-corrosive metallic sheets. The wooden frame was coated with wood primer to avoid fouling (Fig.9).

Three numbers of samplers were used for the study; two of them were placed at Stations I and II and the third one at Poothotta, where spatfall was found to be high (Fig. 1). Each chamber in the sampler was filled with different types of substrates to test the substrate preference of clam larvae for settlement, if any. The substrates used were:-

A.	1)	Terrestrial soil (Panangad)		Poothotta
	2)	Granite Powder		
	3)	Riverine sand		
	4)	Sand + Organic manure		
B.	1)	Station II soil		Thykudam
	2)	Riverine sand		
	3)	Terrestrial Soil (Panangad)		
	4)	Sand + Organic manure		

PLATE V



FIG. X Introduction of S-5 at station I



FIG. XI Introduction of S-5 at station II

C.	1)	Station II soil		
	2)	Station II soil		Irimpanam
	3)	Station I soil		
	4)	Station I soil		

The samplers were lowered manually to depths of 1 m, 3 m & 1.5 m at Poothotta, Thykudam and Irimpanam respectively. The legs of the samplers were anchored to the substratum by means of nylon rope tied to fixed poles.

2.6 Studies on Salinity Tolerance

2.6.1 Test Medium

Fresh sea water collected off Cochin was used as the test medium in the experiment by diluting with dechlorinated tap water to obtain different ranges of salinity. The sea water was allowed to settle and was filtered through a phytoplankton net (bolting silk, No.24) before use. The experiments were conducted at room temperature ($28 \pm 2^\circ\text{C}$),

2.6.2 Test Animals

Apparently healthy live clams (V. cyprinoides) of two different sizes ranging from 10 mm - 20 mm and 21 mm - 35 mm, collected from Station II. were acclimatised for two days in 30 l plastic containers

holding ambient water (1 - 2 ppt). The animals were not fed during these experiments. Aeration was not provided.

2.6.3. Test Containers

The experiments were conducted in 30 l circular plastic containers holding 20 l water (Figs 12 and 13).

2.6.4 Experimental Procedure

Thirteen different salinities (0, 1, 2, 3, 4, 5, 7, 10, 13, 17, 21, 27 and 34.5 ppt were tested in duplicate experiments. The clams were transferred to the basins at the rate of 40 numbers per container. Water exchange (100%) was done once in every 2 days. Each experiment was run for 10 days. Mortality was recorded every 24 hrs and dead animals were removed immediately. Lack of response when pricked with a needle and gaping of shell valves were taken as the criteria for death. Live animals from each concentration were sacrificed on the 1st, 2nd, 3rd, 6th and 10th day of the experiment. Two large and four small clams from each replicate were sacrificed each time to collect the mantle water for estimating its salinity and osmolality.

For estimation of mantle fluid salinity/medium salinity, the same method as described earlier (Section 2.4.2.2) was followed.

PLATE VI



FIG. XII & XIII Experimental set up for salinity tolerance studies



2.6.5 Measurement of Mantle Fluid Osmolality

This was estimated using a GONOTEC OSMOMAT 030 osmometer. The osmolality of the medium was also measured each time.

2.7 Studies on pH tolerance

Test animals were subjected to various pH levels (11, 10.5, 10, 9.5, 9.25, 8.5, 7, 6.03, 4.5, 3.24 and 2.63) by adding required amounts of mineral acids (hydrochloric acid and sulphuric acid) and alkali solutions (sodium hydroxide) to obtain different pH levels. No feed or aeration was provided. Mortality and animal behaviour were recorded every 6 hours and dead animals were removed immediately. Lack of response when pricked with a needle and gaping of shell valves were taken as the criteria for death.

2.8 Data Analysis

a) Length frequency analysis by MODAL PROGRESSION METHOD: Length measurements were grouped into 1 mm size classes. All clams less than 5 mm were considered as spat and were not used in this study, while the clams ranging from 5-19 mm (small) and greater than 19 mm (large) were measured and their percentage frequency was calculated station-wise, for the study period.

b) ELEFAN PROGRAM was applied to fit the von Bertalanffy growth equation to the length frequency data grouped in 2 mm groups (Fig.). Graphs

were plotted based on this. von Bertalanffy's equation was fitted with the observed L and K values, assuming t_0 to be zero, to find out the relative growth of clams.

c) Beverton and Holt (1956) method was used to determine the instantaneous mortality rate, Z , $Z = K (L - \bar{L}) / \bar{L} - L'$ where

\bar{L} = mean length of sample

L' = smallest length of animals that are fully represented in the samples.

L and K = parameters of the von Bertalanffy's Growth Curve

d) **Condition Index and Condition Factor**

The condition index (CI) of individual clams collected from each sampling station was computed every month using the formula:

$$CI = \frac{\text{Wet Flesh Weight}}{\text{Shell on Weight}} \times 100$$

e) **Statistical Treatment of Data**

(1) Analysis of variance (ANOVA) and correlation matrices were worked out for ecological parameters (8x8 and 16x16).

(2) Regression equation of the type $Y = a + bX$ was fitted to the morphometric data. Here, the length (APM) measurements were considered as the independent variable 'X' while the other morphometric and weight parameters were represented as the dependent variable 'Y'; 'a' is the y - intercept and 'b' is the slope.

(3) For length-weight relationships, natural log transformation was made before fitting the above regression equation. The 't' - test was carried out to test the significance of 'b' values of length-weight regressed equations. The method followed to test the length-weight associations at different stations was as given by Newcombe (1936).

(4) Arc Sine Transformation was applied to the salinity tolerance and pH tolerance experimental data and significance of difference between the treatments was tested by F-test.

Chapter III

III - RESULTS

3.1.1 Depth

Depth varied from 0.6 m to 4.2 m between the stations (at the LLWL). The lowest depth was recorded in Stations III and VI, while the maximum depth recorded was in Station II. Stations II (B and C), I(A), IV(B) and V(B) showed depths greater than 4 m. The average depths recorded at all the stations during the study period are given in Table 1.

3.1.2 Transparency

The transparency values ranged from 0.15 m to 0.95 m. Station VI showed the lowest transparency through out the study period. Fig.13 depicts the trend in transparency over the months. Transparency values did not vary significantly between months at a given station while they showed significant variation between stations at 1% level (Table 21a). These variations to some extent appear to be related to the localised activities such as dredging as observed at Station VI.

3.1.3 Temperature

Water temperature (Table 3; Fig.15) varied from 27 to 29°C and the lowest values were recorded during the monsoon season. In July, lowest temperature of 27°C was observed while during April-May highest values prevailed.

Table 1 AVERAGE DEPTH FOR STATIONS

STATION	SUB-STATION	AVERAGE FOR EACH SUB-STATION	AVERAGE FOR THE STATION
I	A	3.18	2.74
	B	3.38	
	C	1.65	
II	A	3.307	3.09
	B	3.5	
	C	2.5	
III	A	1.49	2.7
	B	2.93	
	C	3.68	
IV	A	2.74	3.1
	B	3.5	
	C	2.93	
V	A	2.4	2.9
	B	3.6	
	C	2.6	
VI	A	1.00	1.45
	B	1.45	
	C	1.90	

TREND IN TRANSPARENCY OVER THE MONTHS

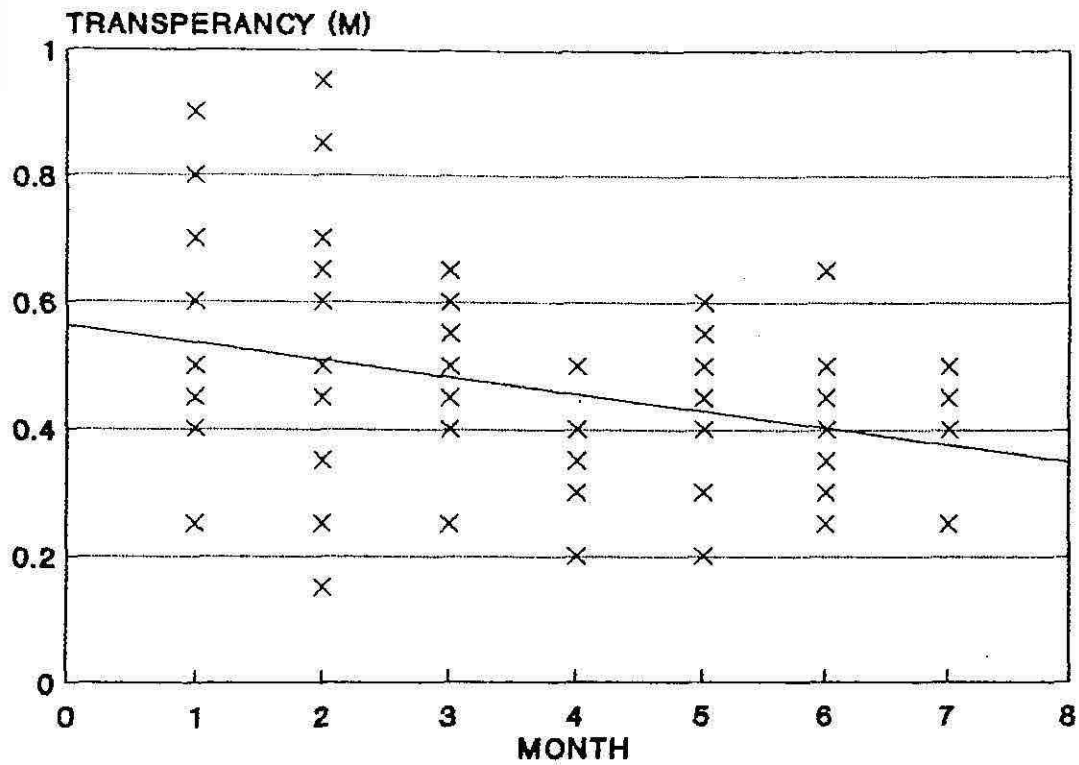


Fig.13

TREND IN DO2 OVER THE MONTHS

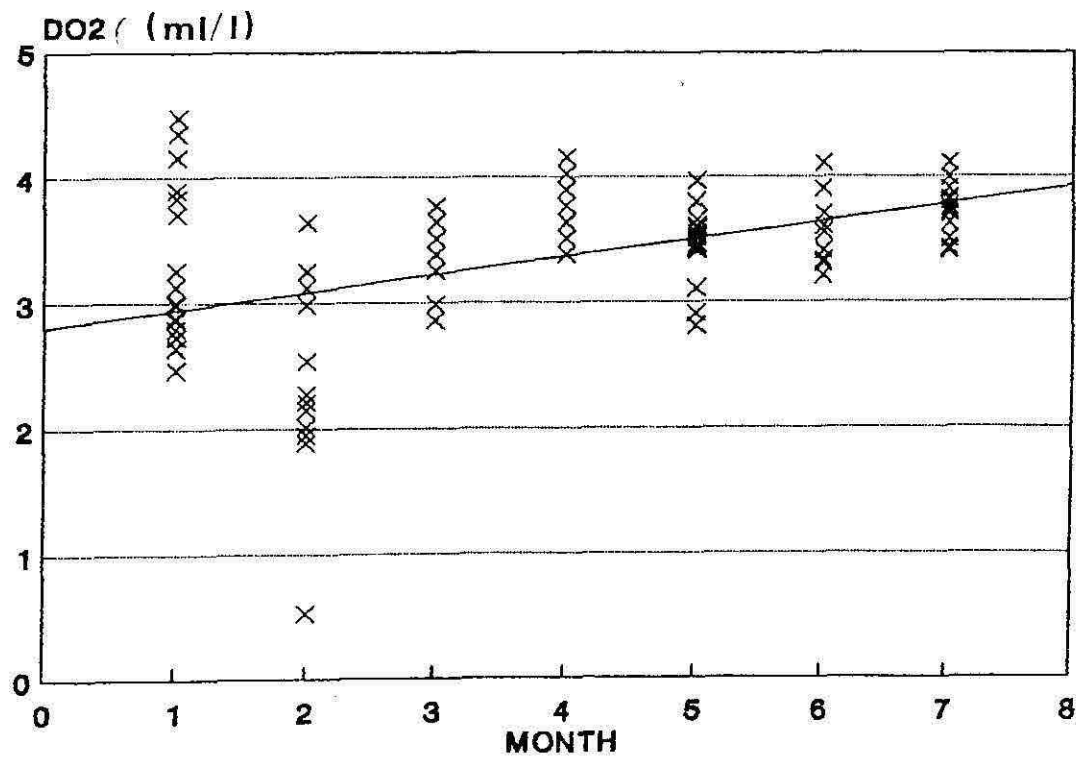


Fig.14

TREND IN TEMPERATURE OVER THE MONTHS

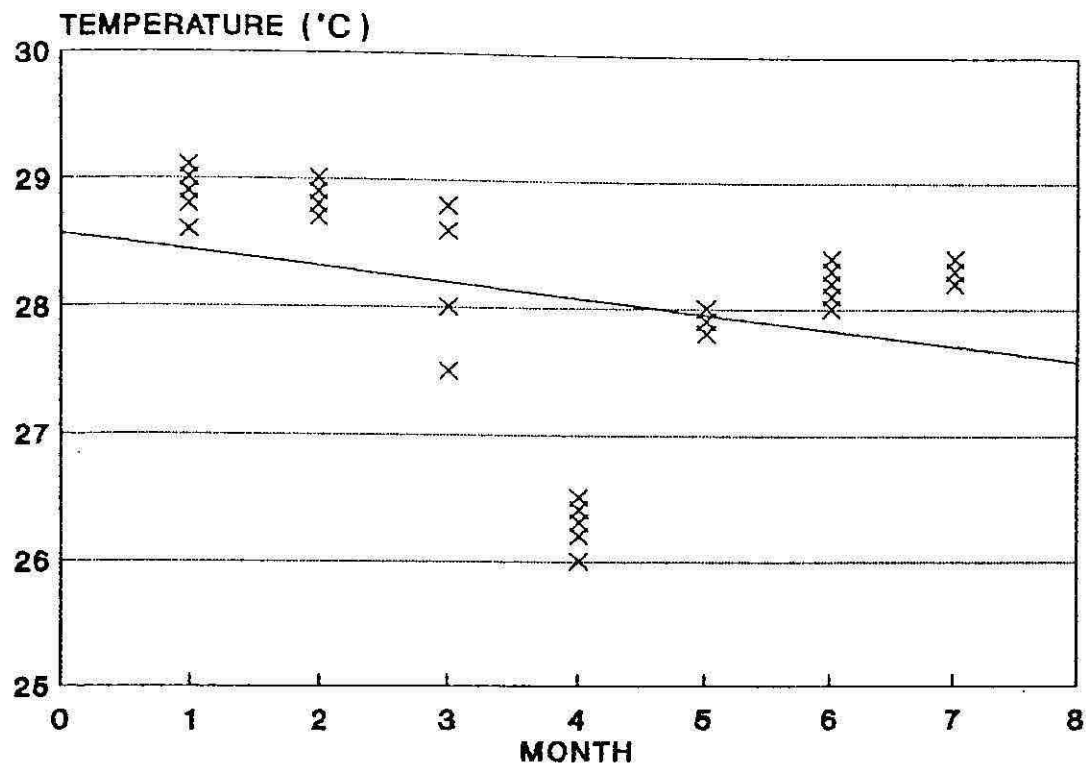


Fig. 15

TREND IN SALINITY OVER THE MONTHS

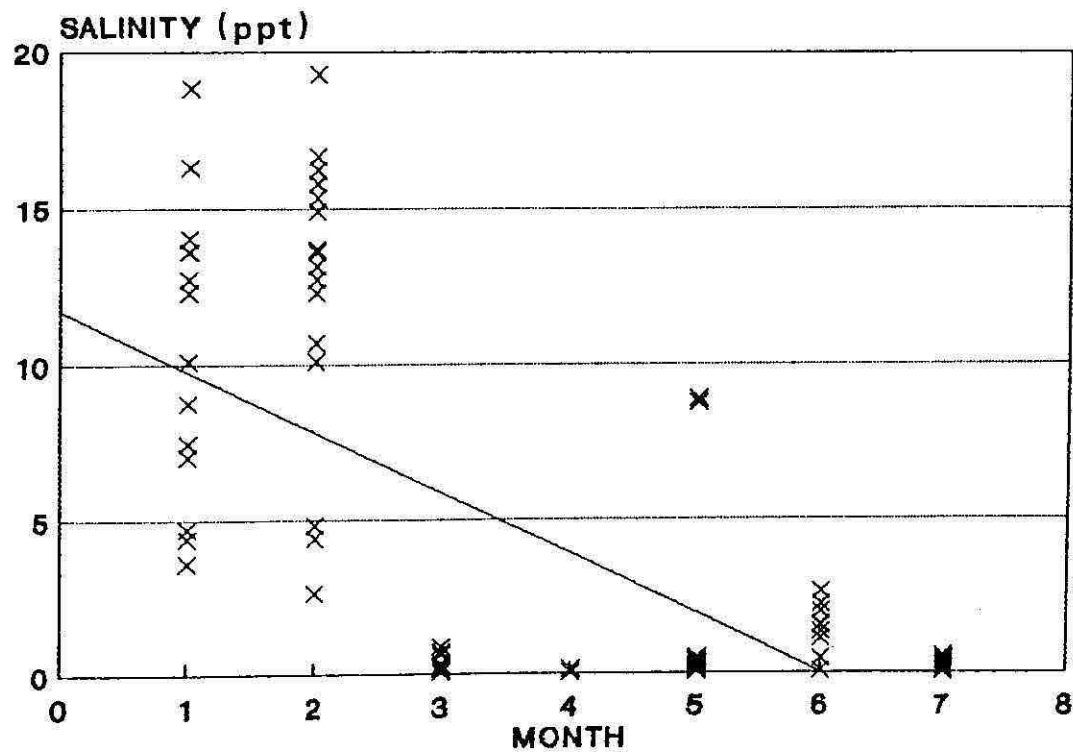


Fig.16

The analysis of variance (ANOVA) showed that the temperature differed significantly between stations and between months at 1% level (Table 21b).

3.2 Analysis of Water Samples

3.2.1 Salinity

The monthly average salinities recorded in each station and along different months are given in the Table 4 and Fig.17. The salinity values, ranged from nil to 19.25 ppt during the study period. The stations in the upstream (I, II and III) showed very low values; all the stations recorded nil ppt in July indicating the heavy fresh water influx due to rains. From June to September at Stations I, II and III low salinities of less than 1 ppt prevailed. But from late September onwards salinity values rose at Stations IV, V and VI gradually. The highest salinity was recorded in the pre-monsoon period (May) in Stations IV and V (19.25 ppt). ANOVA (Table 21c) showed that the differences in the salinity values were highly significant between stations and months at 1% level. The values clearly showed that there was a general increasing trend of salinity values from Station I to VI. Fig. 16 indicates the trend in salinity over the months.

3.2.2 Dissolved Oxygen

In the bottom water, the dissolved oxygen values (Table 2) ranged from 0.52 to 4.79 ml/l with an average of 3.39 ml/l. The peak values were recorded during monsoon months and lowest values during May (Fig.14). Results of

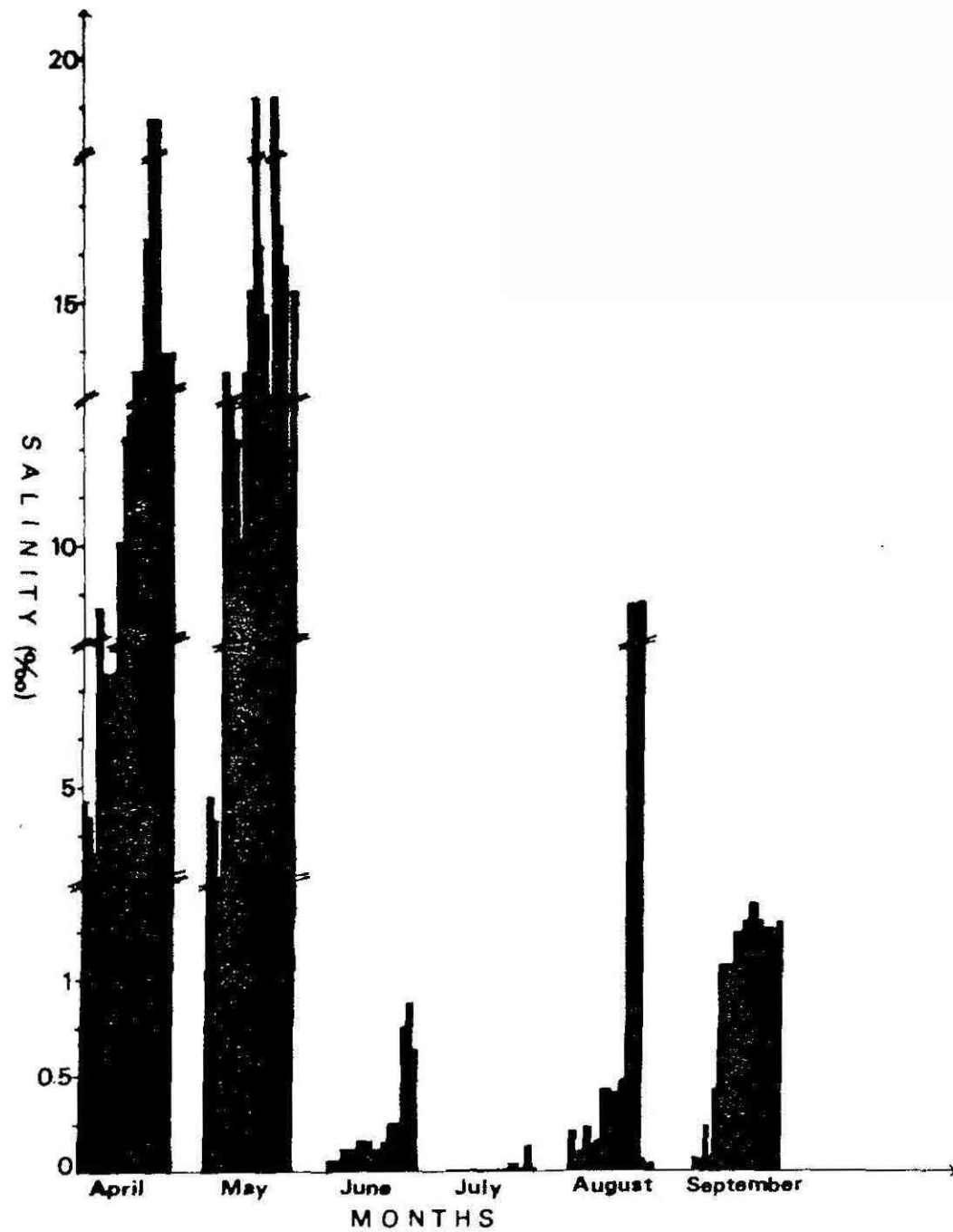


Fig.17 AVERAGE SALINITY PER STATION PER MONTH

the ANOVA (Table 21f) showed significant differences between months at a given station, while they did not vary significantly between stations for a given month even at 5% level. This shows that there is a good movement of water along the subsurface layers.

3.3 Analysis of Sediment Samples

3.3.1 Texture Analysis

The sediment, based on the particle size was classified and brought under the following types as per Brady's (1980) classification (Fig.22).

Clay loam	..	Station I
Loamy sand	..	Station II, IV and VI
Sandy loam	..	Station III
Sandy soil	..	Station V

The average percentage values of sand, silt and clay in the sediments at different stations are given in Table 5, while Figs. 18, 19 and 21 show the trend in these parameters over the months. Except for Station I, sand dominated in all other sediment types. The highest average percentage (95.64) of sand was noted in Station II, while the lowest (45.56%) was noted in Station I. Silt and clay percentages were higher (23.02% and 31.33% respectively) at Station I, while minimum proportions (0.96% and 3.38%) were observed at Station V. For the total study area as a whole, the proportions of sand, silt and clay were 79.48, 7.02 and 13.5% respectively.

TABLE 5 PERCENTAGE TEXTURAL COMPOSITION AND pH OF SEDIMENTS

Station	% Sand			% Silt			% Clay			Soil pH		
	A	B	C	A	B	C	A	B	C	A	B	C
I Avg.	28.88	58.61	49.19	29.12	15.87	24.08	42.06	24.59	26.68	7.09	6.63	6.964
Range	18.5	73.88		5.93	38.9		16.96	43.73		4.53	7.98	
II Avg.	91.31	93.57	85.40	0.30	2.33	2.53	8.37	4.09	11.07	5.031	4.228	4.317
Range	73.52	94.88		0 - 6.36			1.896	22.41		3.25	7.85	
III Avg.	61.63	88.75	75.59	14.73	4.28	9.40	23.62	6.96	14.96	5.71	5.75	5.53
Range	40.83	97.2		0 - 24.13			2.33	35.03		4.75	7.2	
IV Avg.	95.56	90.99	75.44	2.61	3.72	8.92	4.83	5.28	18.0	5.61	5.22	6.031
Range	60.44 - 95.75			0 - 15.82			0.849	23.74			4.00 - 7.00	
V Avg.	98.37	92.90	95.65	0.61	1.81	0.47	1.02	5.25	3.88	5.464	6.088	6.194
Range	85.85 - 99.12			0 - 3.4			0.4	10.64		7.94	4.72	
VI Avg.	68.99	91.18	88.63	12.19	2.35	3.85	18.33	6.47	8.67	7.225	6.458	7.097
Range	59.85 - 99.08			0.42 - 19.62			0.42	24.09			5.32 - 8.57	

TREND IN SAND(%) OVER THE MONTHS

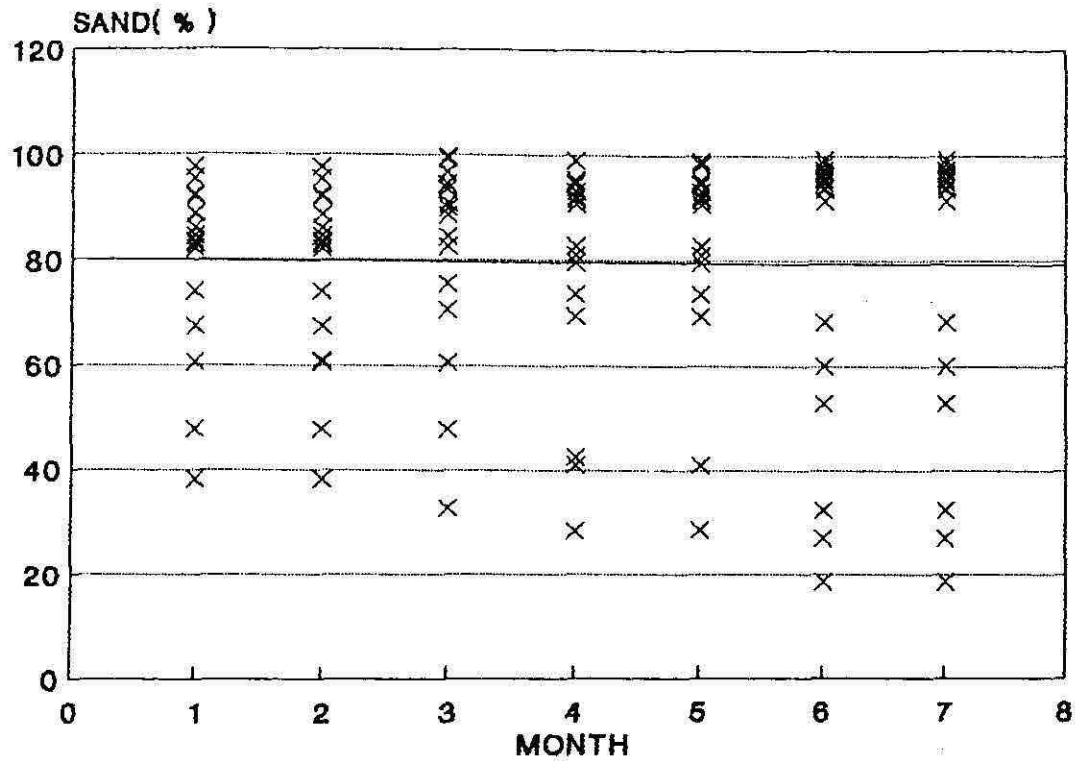


Fig.18

TREND IN SILT(%) OVER THE MONTHS

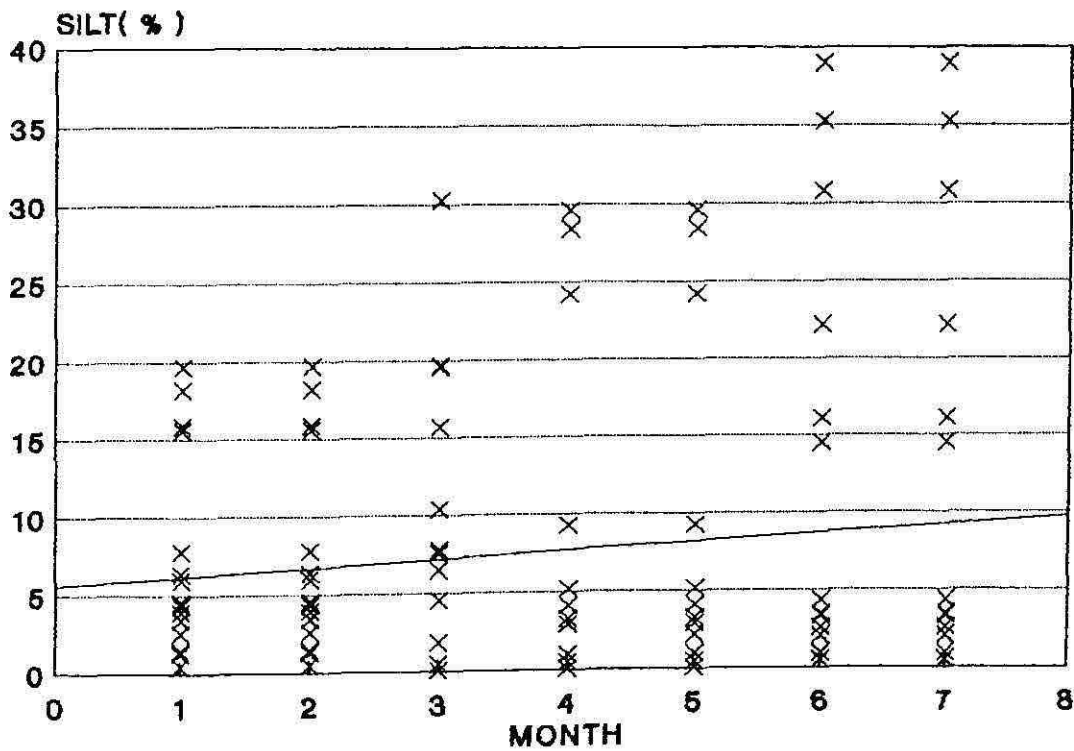


Fig.19

TREND IN ORGANIC CARBON OVER THE MONTHS

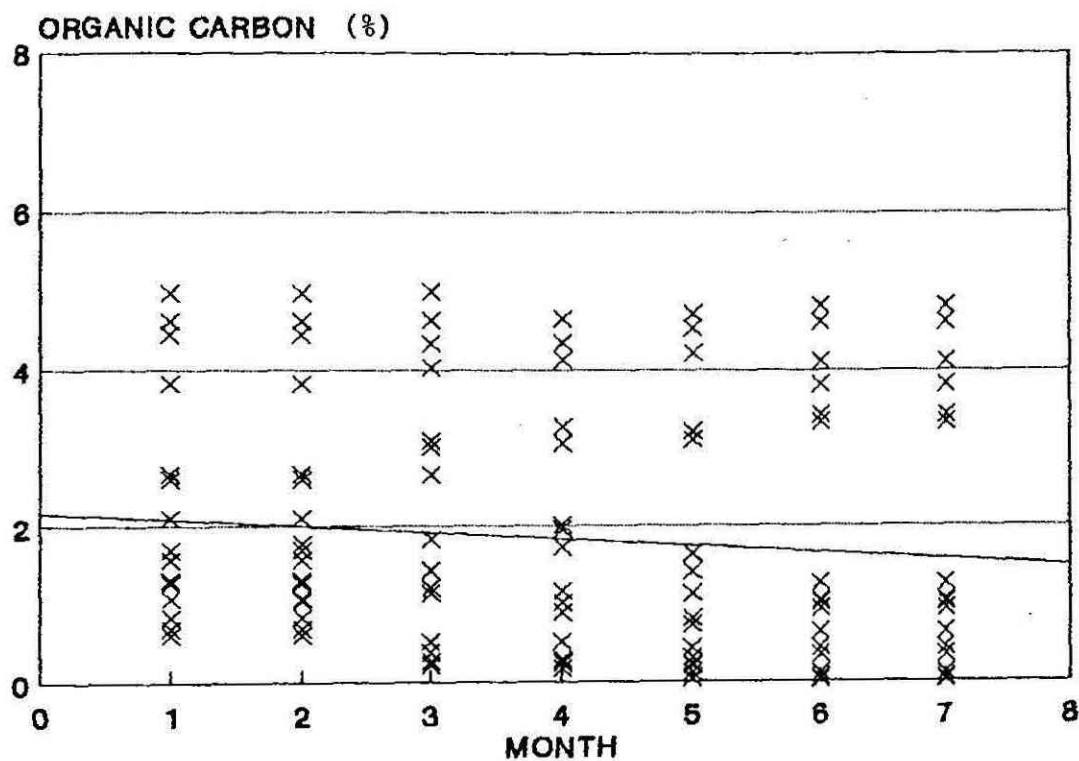


Fig.20

TREND IN CLAY(%) OVER THE MONTHS

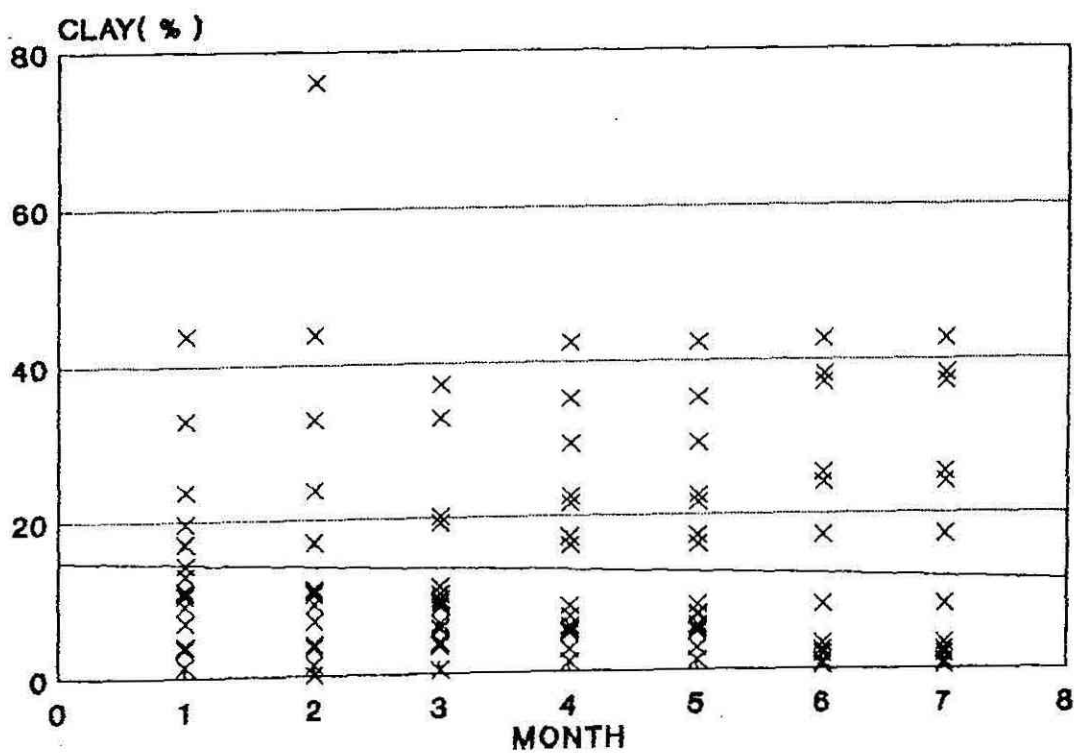


Fig.21

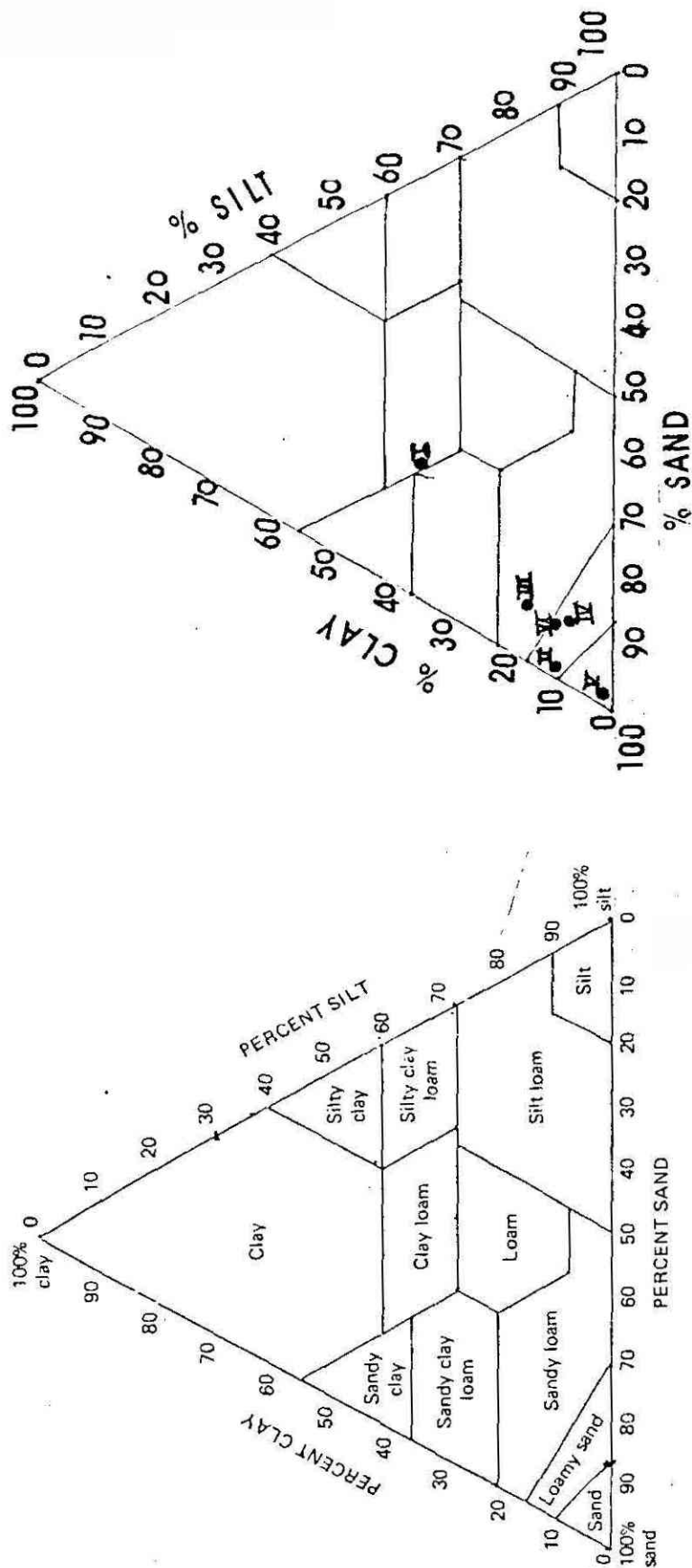


Fig. 22 Relationship between the class name of a soil and its particle size distribution. In using the diagram the points corresponding to the percentages of silt and clay present in the soil under consideration are located on the silt and clay lines respectively. Lines are then projected inward, parallel in the first case to the clay side of the triangle and in the second case parallel to the sand side. The name of the compartment in which the two lines intersect is the class name of the soil in the respective stations.

Results of ANOVA (Table 21j,k,l) showed significant differences in percentage of sand and silt between stations and months at 1% level, while % clay differed significantly at 1% only between months and differed between stations at 5% level. The sediment colour at Station I and VI was dark brown to black, while the sediments of other stations showed grey colour. The sand fractions in the sediment from the upstream stations were finer than those in the stations located down stream (IV and V); however Station VI also showed finer sediments. There is a good correlation between clay and silt.

3.3.2 Estimation of organic content

The monthly average values of organic carbon. Organic matter and organic nitrogen for each station are shown in the Table 6. The general trend in the organic carbon content of the sediments during the seven months is shown in the Fig.20.

The organic carbon values of the sediment were generally high and ranged from 0.009 to 4.98% and the mean value was observed to be 1.83%. The maximum values greater than 4% were noticed at Station I throughout the study. The organic matter in the sediment varied from 0.061 to 8.58% (average 3.16) and nitrogen from 0.0008 to 0.429% (average 0.15%). The percentage of organic matter and organic nitrogen values were greater than 7 and 0.4 respectively at Station I. The lowest values of less than 1% organic carbon were observed at Station V, that too predominantly in the monsoon months and similarly less than 2% and 0.1% for organic matter and nitrogen respectively at Station V.

TABLE: 6 PERCENTAGE COMPOSITION OF ORGANIC CONSTITUENTS IN SEDIMENTS

Station	Organic Carbon			Organic matter			Organic Nitrogen		
	A	B	C	A	B	C	A	B	C
I Avg.	4.066%	4.778%	4.614%	7.010	8.237	7.955	0.351	0.412	0.398
Range	3.813 -	4.98%		6.574 -	8.586		0.329 -	0.429	
II (Avg)	0.631%	0.466%	1.543%	1.088	0.803	2.660	0.054	0.040	0.133
Range	0.30 -	1.821%		0.517 -	3.139			0.026 -	0.157
III (Avg)	3.178%	1.775%	1.711%	5.479	3.060	2.950	0.274	0.153	0.147
Range	1.01 -	4.433%		1.741 -	7.642		0.087 -	0.382	
IV (Avg)	0.566%	0.613%	2.569%	0.976	1.057	4.429	0.049	0.053	0.221
Range	0.020 -	3.42%		0.034 -	5.896		0.002 -	0.295	
V (Avg)	0.299%	0.368%	0.648%	0.515	0.634	1.117	0.026	0.032	0.056
Range	0.009 -	1.035%		0.016 -	1.784		0.0008 -	0.089	
VI (Avg)	3.161%	0.795%	1.187%	5.440	1.371	2.046	0.273	0.069	0.102
Range	0.09 -	4.02%		0.155 -	6.930		0.008 -	0.347	

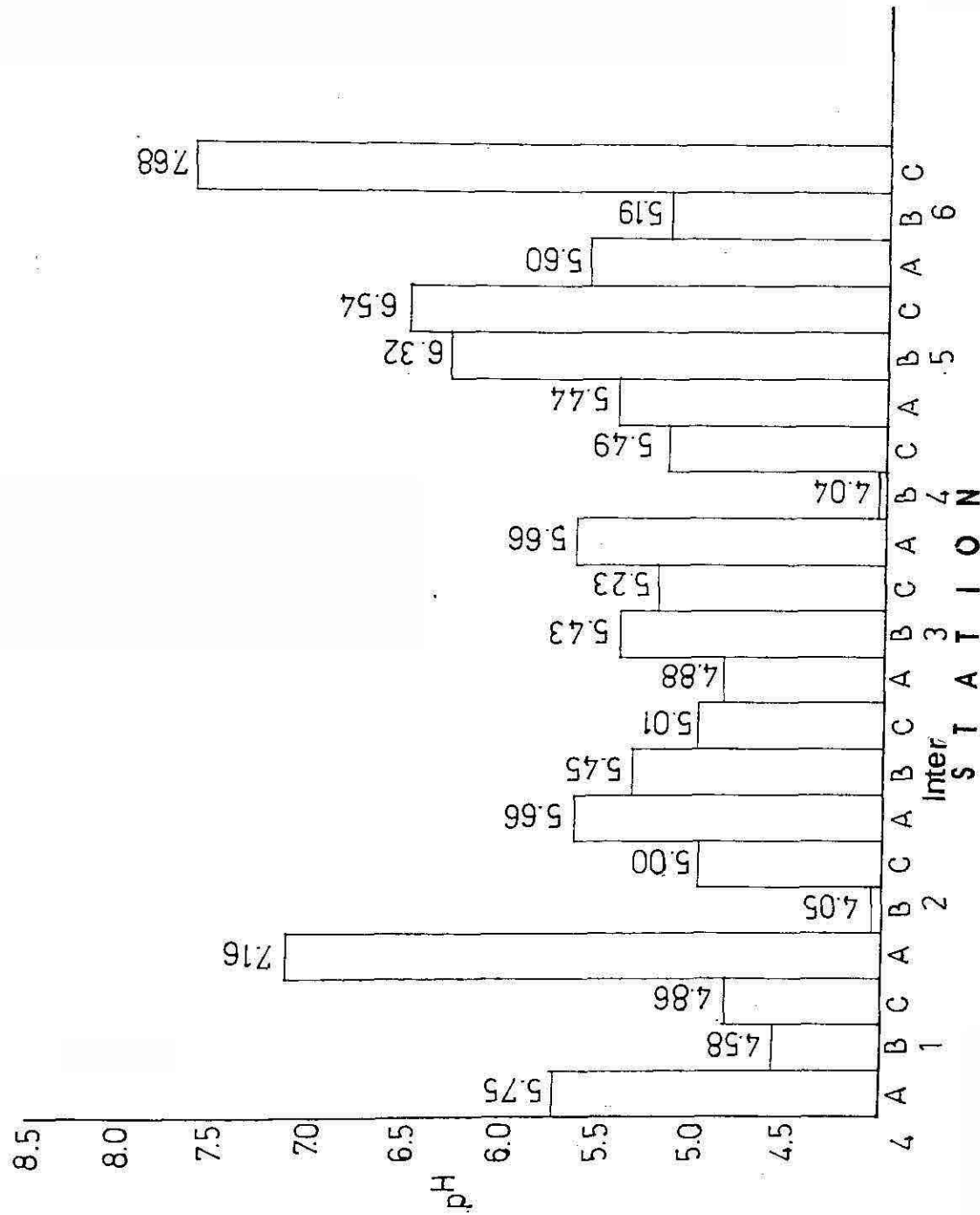


Fig.23 pH OF SOIL (premonsoon)

* Inter - a site between stations II and III

The results of ANOVA (Table 21g,h,i) showed that the organic carbon values differed significantly between stations and also between months.

3.3.3 Soil Salinity

The highest values were recorded from Station I in May and the lowest from V station in July. Results of ANOVA (Table 21d) showed that the soil salinity values differed significantly between months but not between station at 1% level.

Thus, based on the various physical and chemical parameters of water and sediment it is clearly evident that the six stations in the study area differed significantly. The exceptions to this pattern are the values of dissolved oxygen and transparency of the water, column.

3.3.4 Soil pH

The pH ranged from 3.25 to 8.57 (Table 5; Fig.23). The lowest pH value was recorded instation VI and I and the highest average value in Station I and VI ANOVA (Table 21c) showed the pH values differed significantly between months at 1% level).

3.4 Population Density

3.4.1 Numbers of Clams per square metre

The density distribution of V. cyprinoides during the seven months of study at different stations is represented in Tables 9a, 9b, 9c and Fig.24.

TABLE: 9 a ABUNDANCE OF LARGE CLAMS OVER SEVEN MONTHS

STATION	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	MEAN	SD
I	--	--	--	--	--	--	--	--	--
II	204	116	102	50.67	108	728	321.33	232.38	147.005
III	77.33	38.67	10.67	51.33	88.67	36	60	19.72	24.473
IV	--	--	--	--	76	32	109.3	30/67	41.405
V	126	141.33	158.67	140	81.33	162.67	217.33	144.38	38.102
VI	149.33	25.33	--	--	28	8	26.67	33.91	48.482

TABLE 9 b. ABUNDANCE OF SMALL CLAMS OVER SEVEN MONTHS.

STATION	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	MEAN	SD
i	--	--	--	--	--	--	--	--	--
II	6300	3526.67	4706.67	5288	6732	217.33	310.67	3620.07	2476.616
III	2333.33	1197.33	1902.67	4973.33	6064	4789.33	7722.67	4140.38	2222.687
IV	--	--	--	--	85.33	1494.67	5824	1057.72	2011.715
V	--	--	--	--	--	--	--	--	--
VI	6.67	280	--	13.33	5.33	6.67	--	44.57	96.206

TABLE 9 C. ABUNDANCE OF SPAT OVER SEVEN MONTHS

STATION	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	MEAN	SD
I	--	666.67	--	--	--	550	166.67	202.38	267.622
II	183.3	3666.67	1166.7	--	--	2333.33	2833.33	1454.76	1371.127
III	750	4033.33	366.67	250	550	2250	4833.33	1821.481	1751.997
IV	550	916.67	250	166.67	916.67	1750	3250	1119.04	1000.492
V	166.67	783.33	550	550	83.33	916.67	1166.67	611.91	361.483
VI	--	550	250	333.33	--	416.67	666.67	321.43	236.711

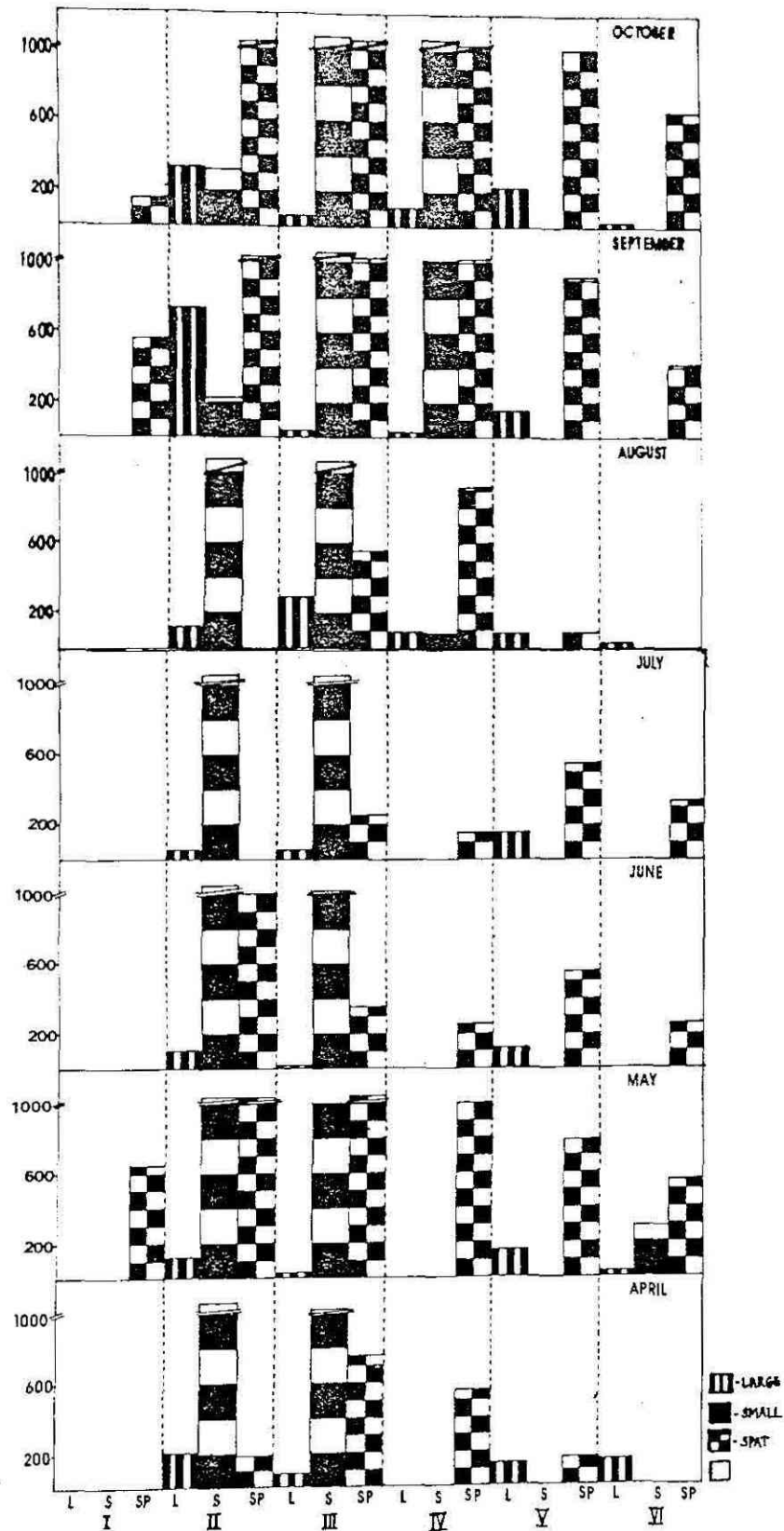


Fig.24 ABUNDANCE OF *V. CYPRINOIDES* IN DIFFERENT STATIONS DURING THE STUDY PERIOD

(a) **Station I**

Though occasional samples of spat were obtained from this station during May, September and October with an average of $202/\text{m}^2$, the total absence of clams (both small and large) is a notable feature in this station.

(b) **Station II**

Unlike Station I, this station showed the presence of clams of small and large sizes in all the months with the density ranging from $24-1,056/\text{m}^2$ (large) and $72-9,920/\text{m}^2$ (small) with the average values at $232/\text{m}^2$ and $3620/\text{m}^2$, Spat was collected in all the months except for July and August, at an average density of $1455/\text{m}^2$ (range $75-6,200/\text{m}^2$).

(c) **Station III**

At this station also both small and large clams were present in all the seven months with the density ranging from $20-212/\text{m}^2$ (large) and $28-13,248/\text{m}^2$ (small), at an average of $20/\text{m}^2$ and $4140/\text{m}^2$ respectively. An exceptionally high density of small clams at $13,248$ and $10,048/\text{m}^2$ were recorded from III C and III B during August and October respectively. The spat occurred in all the months except for July, and the numbers varied from $250-6000$ at an average of $1822/\text{m}^2$. Substation III A was very shallow and sometimes negligible number of clams were recorded.

(d) **Station IV**

At this station the river has maximum width. Though spat was recorded in all the months (average $1120/\text{m}^2$, range $250\text{--}3750/\text{m}^2$). Large and small clams were collected only during August–October, that too from substations A and B. The largest clam (54 mm) in the present study was collected from this station. The density of large and small clams ranged from $12\text{--}300/\text{m}^2$ (average $31/\text{m}^2$) and $80\text{--}16,702/\text{m}^2$ ($1056/\text{m}^2$) respectively.

(e) **Station V**

At this station large clams, more or less uniform in density, were recorded through out the study. Their density ranged from $16\text{--}244/\text{m}^2$ and averaged at $144/\text{m}^2$. The spat was recorded in all months and the density ranged from $100\text{--}1500$ with an average of $612/\text{m}^2$; small clams rarely occurred at this station.

(f) **Station VI**

Except for the months of June and July, large clams were collected at an average density of $34/\text{m}^2$ (range $24\text{--}236/\text{m}^2$). Small clams were not recorded during June and October, and the remaining months showed an average of $45/\text{m}^2$ (range $16\text{--}840/\text{m}^2$). The spat were collected in all the months except for April and August. Their density ranged from $250\text{--}1750/\text{m}^2$ and the average was $321/\text{m}^2$. Substation VI C showed the maximum number of small and large clams, while in Substations A and B, large and small clams were absent.

(g) **Distribution of clams between stations**

Based on the density of clams and spat during the study period the stations can be ranked as follows:

<u>Large Clams</u>	<u>Av. No./m²</u>	<u>Variance</u>	<u>Rank</u>
Station II	233	21610.47	1
Station V	144	1451.76	2
Station III	52	578.93	3
Station VI	34	2350.50	4
Station IV	31	1714.37	5
Station I	-	Nil	6

<u>Small Clams:</u>	<u>Av. No./m²</u>	<u>Variance</u>	<u>Rank</u>
Station III	4140	494033.75	1
Station II	3869	6133626.8	2
Station IV	1058	4046997.24	3
Station VI	45	9255.59	4
Station V	-	-	5
Station I	-	-	6

<u>Spat:</u>			
Station III	1862	3069493.49	1
Station II	1455	1879989.25	2
Station IV	1114	1000984.24	3
Station V	602	130669.96	4
Station VI	317	56032.10	5
Station I	197.62	71621.53	6

3.4.2 Biomass

Table 10 and Fig.25 gives the monthly average biomass values recorded at stations. The biomass values, computed on the basis of shell on weight for all the stations during the study period, ranged from 0 to 42969.236 g/sq.m. The average values of biomass for different stations were 6145.920 g/m² (Station II), 6847.846 g/m² (Station III), 4137.900 g/m² (Station IV), 3426.160 g/m² (Station V) and 439.50 g/m² (Station VI). The values recorded in stations I and VI were considerably low, while Stations II, III, IV and V indicated high values of standing stocks. Exceptionally high biomass values recorded in some of the stations during certain months are 42969.236 g/m² (IV_B), 27816.480 g/m² (III_B), 22620.512 g/m² (IV_A) and 21807.860 g/m² (III_C).

3.5 Age and Growth

3.5.1 Modal Progression Method based on length Frequency Data

Analysis of data was not possible for Station I due to non-availability of samples in sufficient numbers.

Station II

The size classes representing this station during the study period (Fig.26a to g) were between 5 and 47 mm and the observed monthly modal

TABLE 10 MONTHLY AVERAGE BIOMASS AT EACH STATION

Station	Biomass						
	April	May	June	July	Aug.	Sept.	Oct. Mean
1	0.266	2.66	0	0	0.333	2.333	0 0.333
2	5220.05	3156.30	3261.62	4307.26	9080.80	11469.45	6525.97 6145.92
3	2587.88	-	1833.27	-	3075.85	10200.79	16541.44 6847.846
4	2.33	3.666	1	0.666	2592.06	10267.22	16098.39 4137.90
5	1886.02	2999.19	3818.11	3085.13	2297.15	3835.28	6062.29 3426.16
6	1898.79	514.25	1	366.12	-	278.83	139.31 439.50

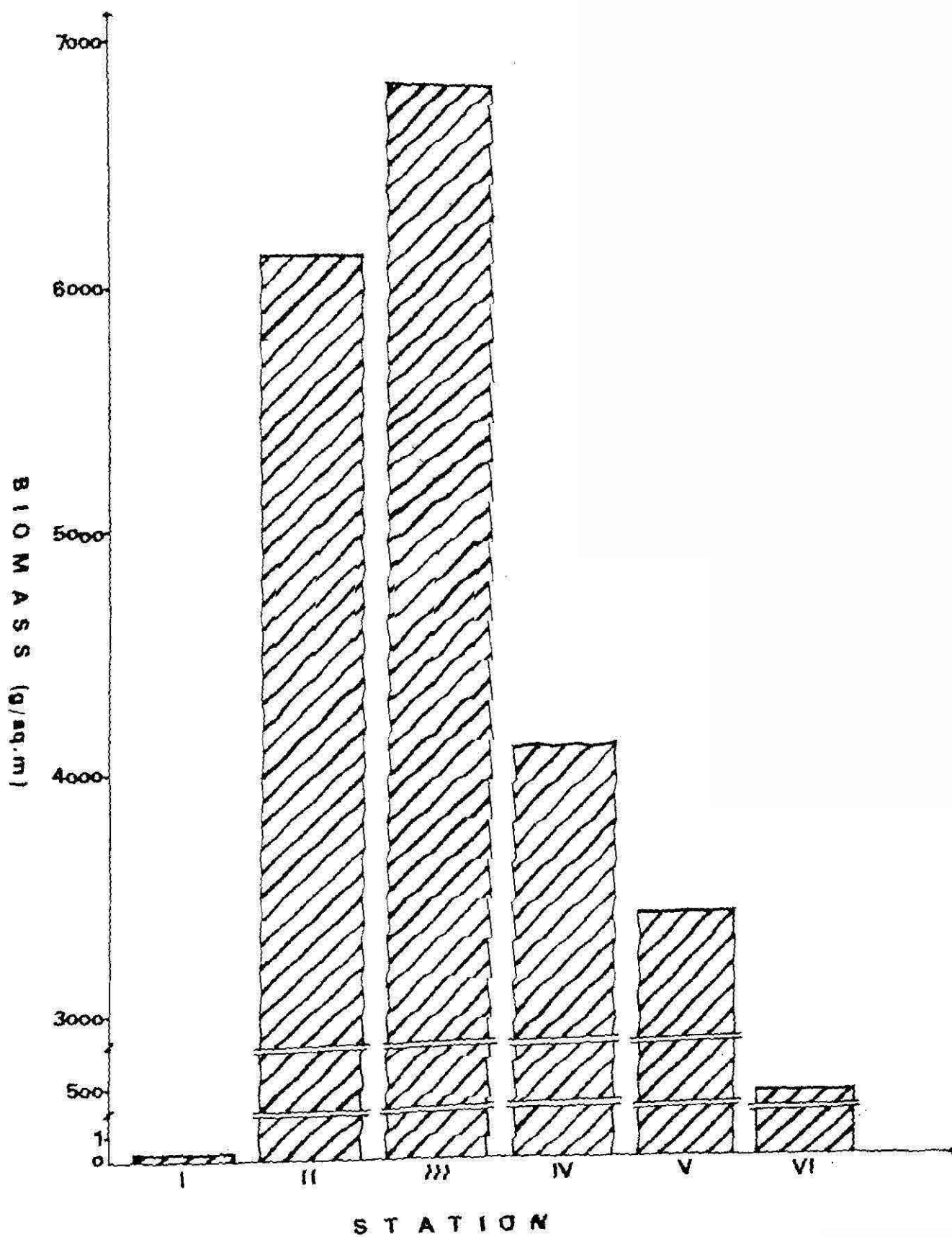


Fig.25 AVERAGE BIOMASS PER STATION PER MONTH

classes were 9 mm (April) 10 mm (May), 12 mm (June), 14 mm (July), 14 mm (August) 19 mm (September) and 20 mm (October). It is clear that in 6 months, the clams have grown from 10 mm to 20 mm.

Station III

The size classes ranged between 8 and 47 mm (Fig. 27a to g) and the modal lengths obtained were 13 mm (April), 13 mm (May), 13 mm (June) 15 mm (August), 15 mm (September) and 15 mm (October). The modal progression was slow, with the same size group persisting for several months.

Station IV

Clams were collected only during August - October; they varied in length from 14-52 mm and the observed modal classes were 17 mm (August) 20 mm (September) and 21 mm (October) (Fig. 28a to c).

Station V

Larger clams dominated the collection at this station (Fig. 29a to g) length varied from 15-50 mm. The modal values were 36 mm (April), 38 and 32 mm (May), 38 and 41 mm (June), 39 and 42 mm (July), 15 and 42 mm (August), 40 mm (September) and 43 and 44 mm (October). The data suggests that clams measuring 36 mm in April have grown to 42.5 mm in October.

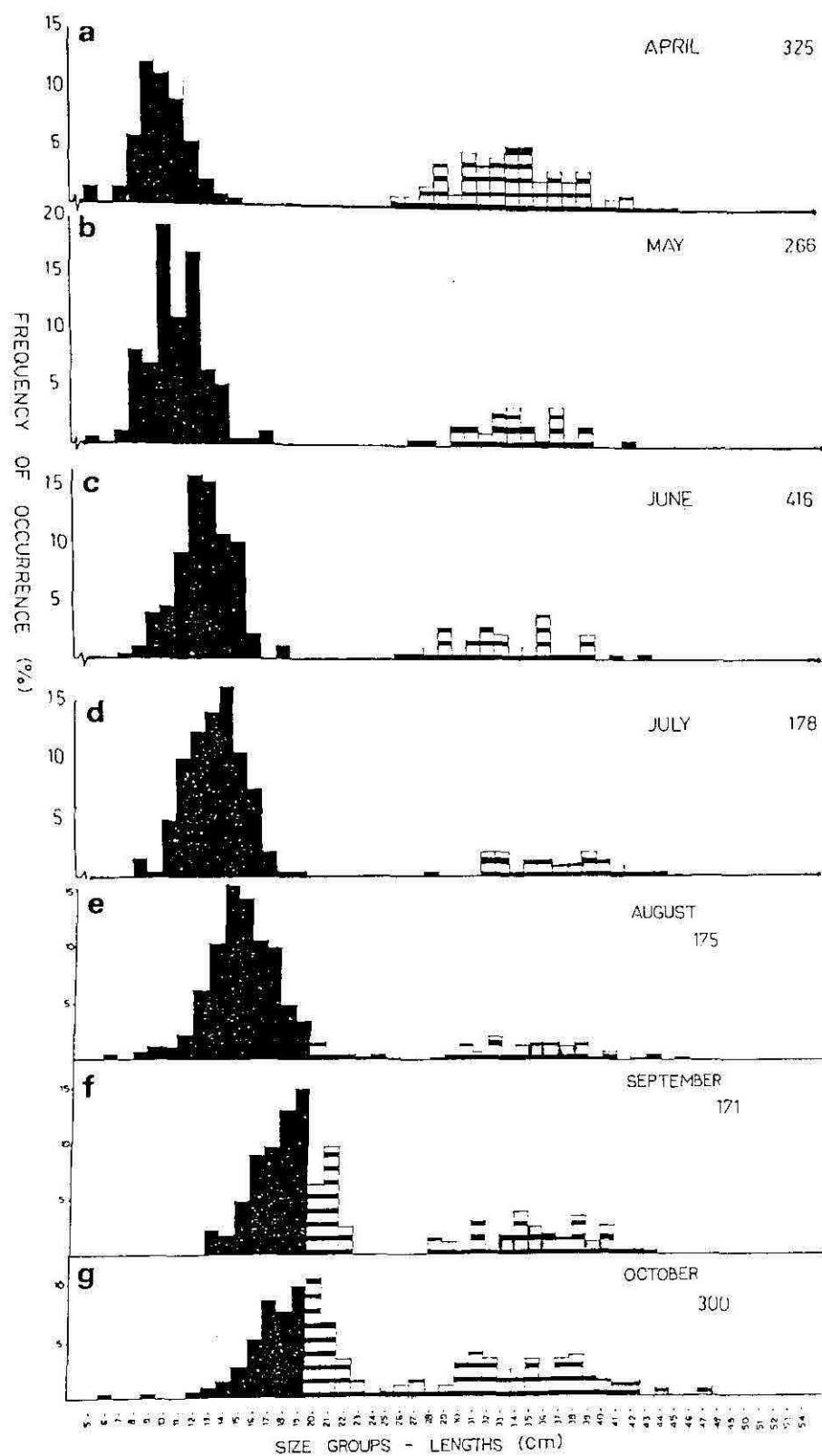


Fig. 26 a to g SIZE FREQUENCY OCCURENCE (%)
OF CLAMS- STATION II

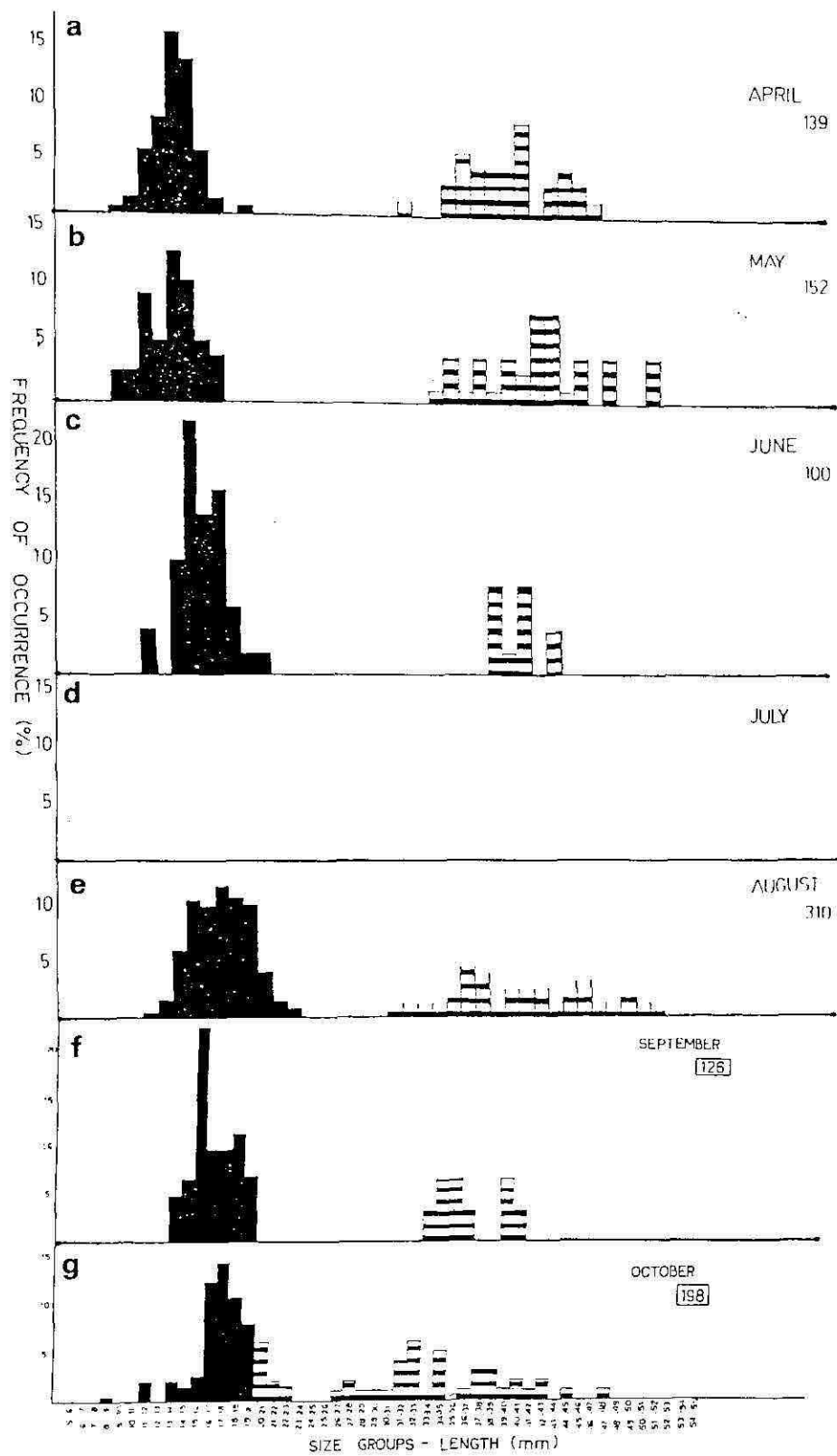


Fig.27 a to g SIZE FREQUENCY OCCURENCE (%)
OF CLAMS- STATION III

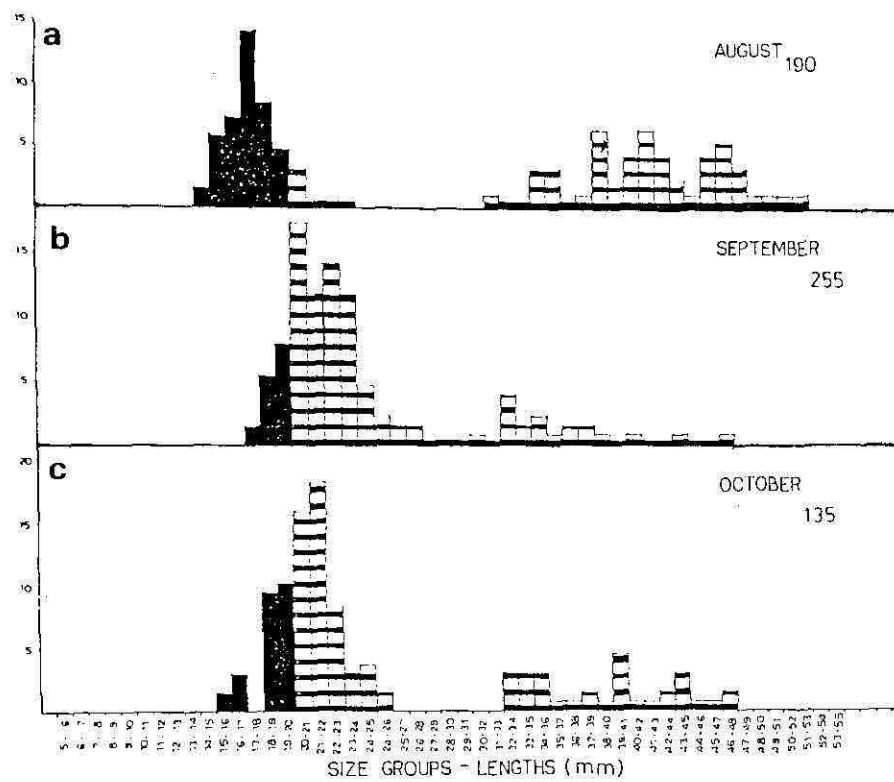


Fig.28 a to c SIZE FREQUENCY OCCURENCE (%)
OF CLAMS - STATION IV

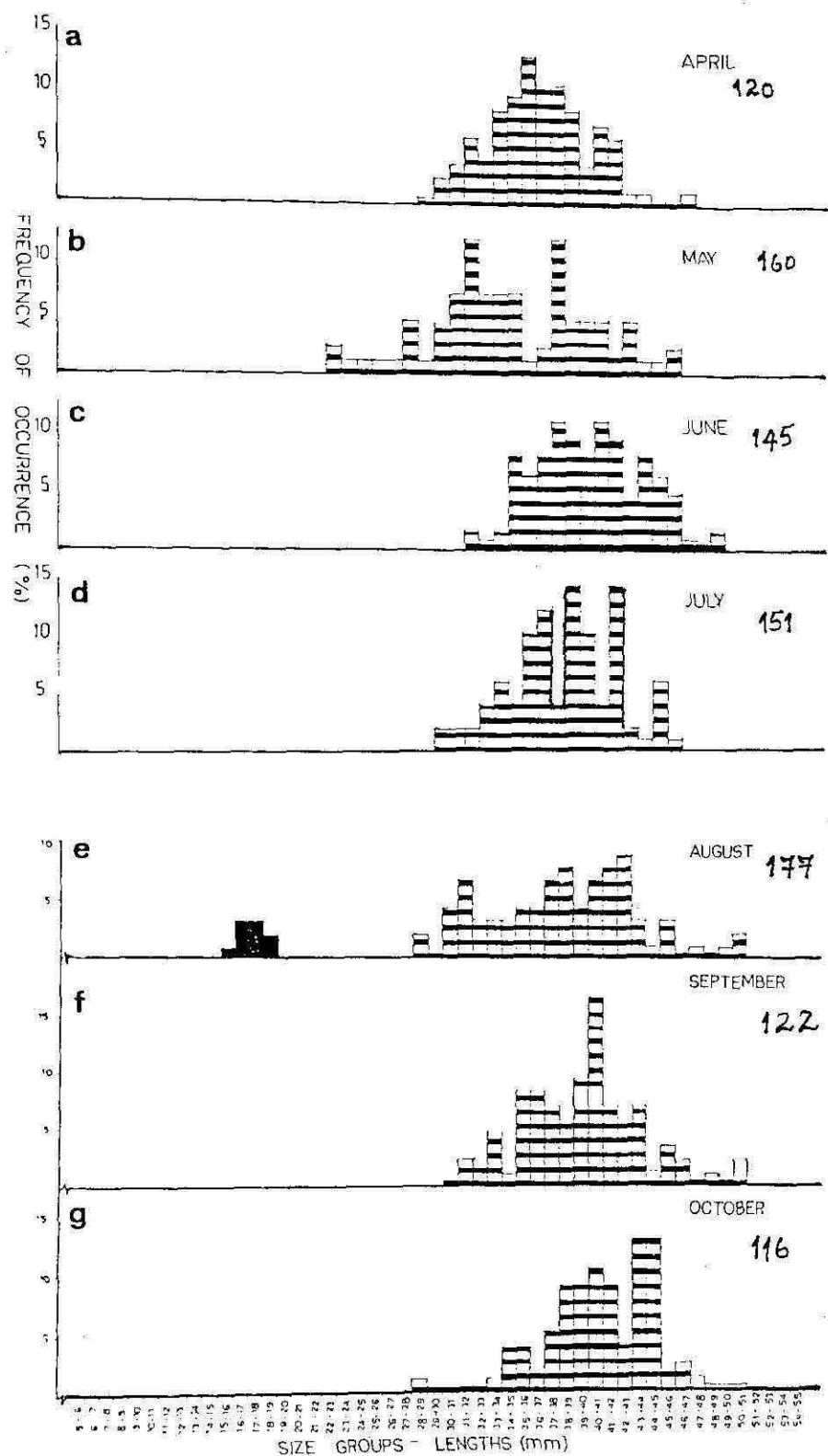


Fig.29 a to g SIZE FREQUENCY OCCURENCE (%) OF CLAMS - STATION V

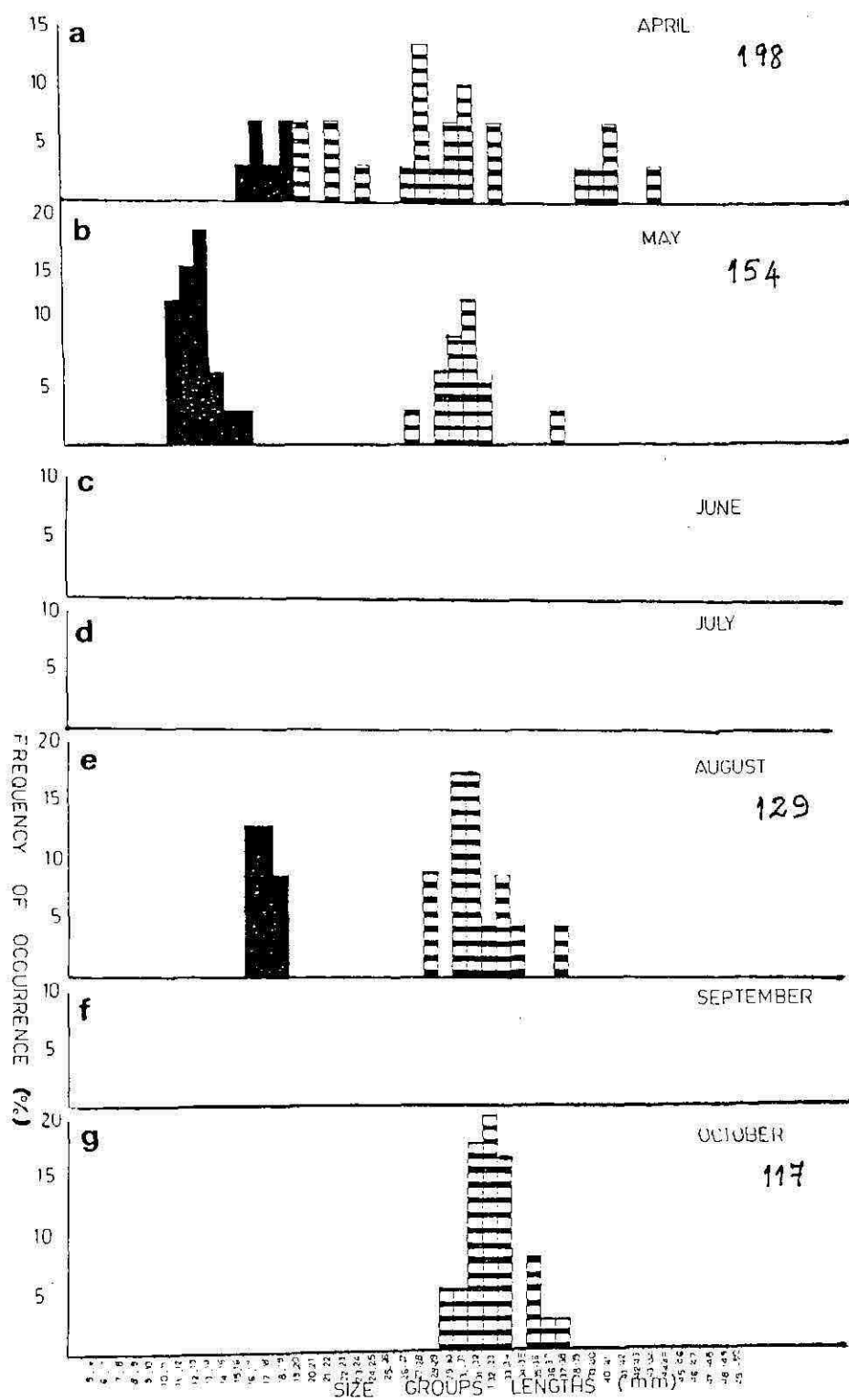


Fig.30 a to g SIZE FREQUENCY OCCURENCE (%) OF CLAMS-STATION VI

Station VI

The observed size classes at this station were between 11 mm and 44 mm and the modal values were: 17 and 19 mm in April, 13 mm in May, 16-17 mm in August and 32 mm in October (Fig.30a to g). This station showed patchy and skewed distribution of clams.

3.5.2 von Bertalanffy growth model

The parameters of the von Bertalanffy growth formula, as computed by ELEFAN program are given below:

Asymptotic length	(L_{∞})	= 58 mm
Growth co-efficient	(K)	= 0.56 (annual basis)
Theoretical origin of the growth curve	(t_0)	= 0 (assumption)

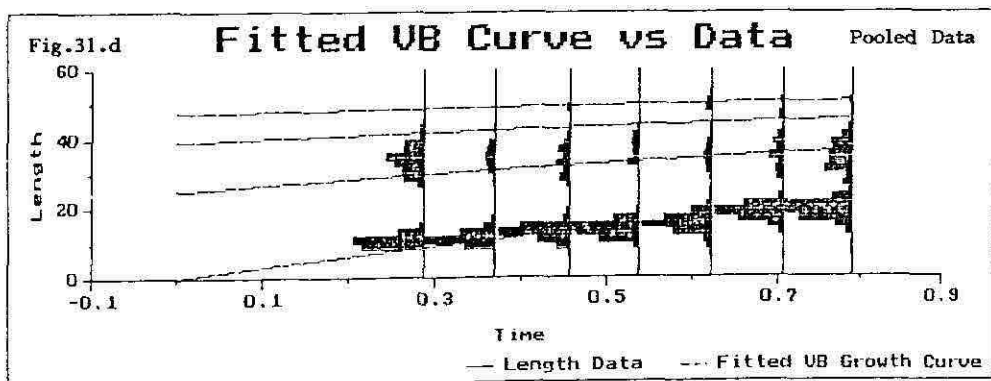
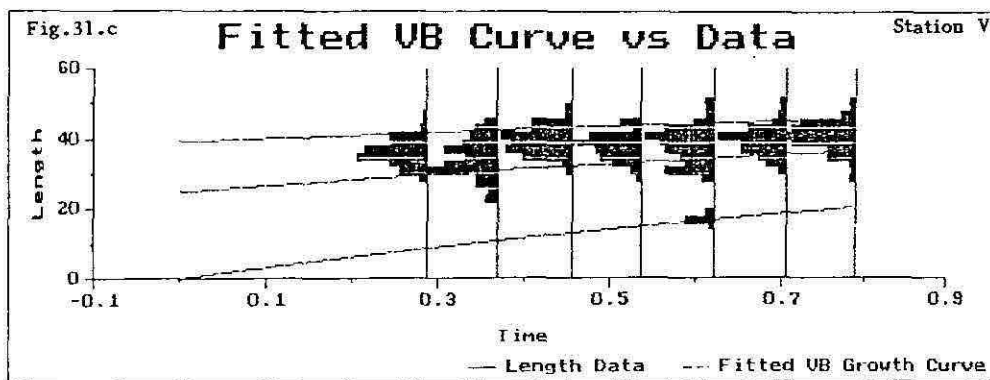
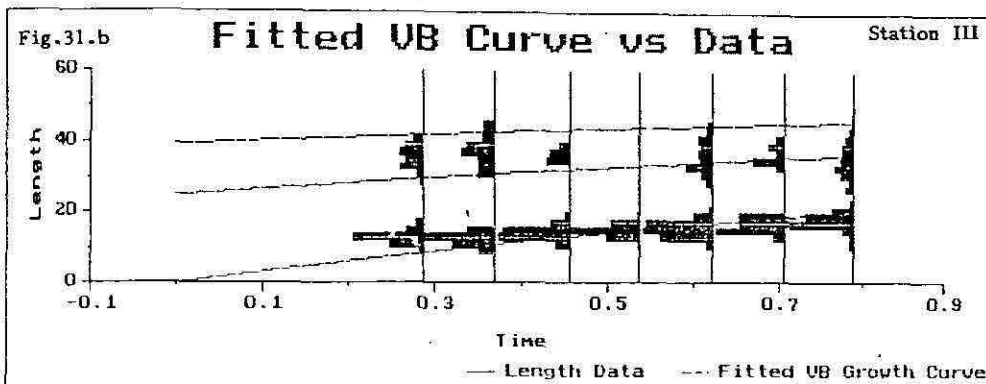
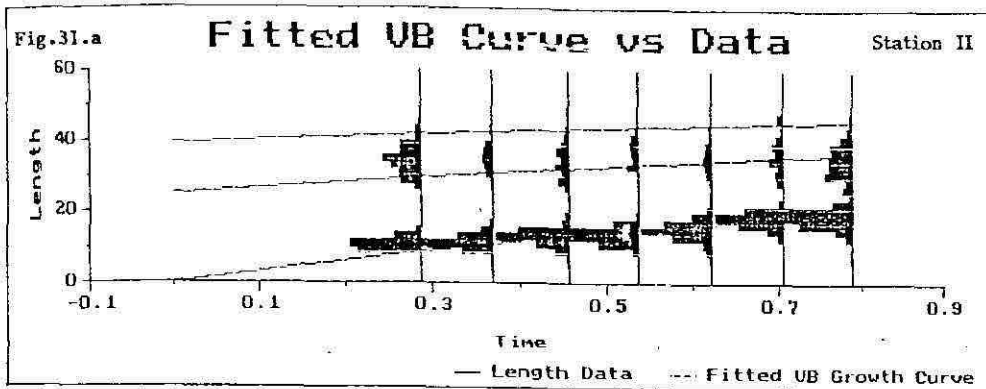
The von Bertalanffy growth equation obtained is written as:

[L_t is length at time 't', 'e' is the base of Neperian logarithm.]

The estimated lengths at different ages $L_t = 58 (1 - e^{-0.56(t)})$, where,

(Fig.31a to d) obtained by applying the von Bertalanffy growth equation, are given below:

- (i) Relative length after 6 months = 14.16 mm
- (ii) Relative length after 1st year = 24.6 mm



- (iii) Relative length after 2nd year = 39.09 mm
- (iv) Relative length after 3rd year = 47.19 mm
- (v) Relative length after 4th year = 51.83 mm

The largest specimen obtained in the collections measured 54 mm.

3.5.3 Morphometric Relationships

The stationwise regression equations for the various morphometric characters are given in Table 11. The 'b' values for length (APM)-height (DVM) ranged from 0.6676 to 0.8882 and the 'r' values from 0.8135 to 0.9730. The 'b' values for length (APM) to depth equations varied from 0.4681 to 0.6791 and 'r' values varied from 0.6088 to 0.9643. The 'b' values were observed to be less than 1 in both the cases; they were close to unity in APM-DVM equations while distinctly lesser than the 1 in the case of APM-Depth. The 'r' values showed significant correlation between the parameters studied.

Length-weight Relationships

The length-weight data fitted to the regression equation for various parameters are given in Table 11 and are represented in Figs. 32.1 to 32.5.

In the length-shell-on-weight regression equation, the 'b' values ranged from 2.0601 to 2.9621 and 'r' values from 0.7743 to 0.9706. The length-flesh weight regression equations gave 'b' values ranging from 1.8418 to 2.4486

TABLE : 11 REGRESSION EQUATIONS FOR MORPHOMETRIC
AND LENGTH - WEIGHT RELATIONSHIPS

STN	PARAMETERS RELATED TO LENGTH-X	TOTAL NO. OF CLAMS.	REGRESSION EQUATIONS	(FIG. NO.)	'r' VALUES	SIGNIFI- CANCE OF 'b'
II	DEPTH	460	$Y = 1.6354 + 0.589411 x$	(a)	$r = 0.8339$	--
	DVM	460	$Y = 2.2771 + 0.8091 x$	(b)	$r = 0.8853$	--
	SOW	460	$\log Y = -6.9418 + 2.7162 \log x$	(c)	$r = 0.9455$	No
	FW	460	$\log Y = -8.1259 + 2.4486 \log x$	(d)	$r = 0.8782$	No
	DW	460	$\log Y = -9.7055 + 2.3481 \log x$	(e)	$r = 0.7094$	No
III	DEPTH	420	$Y = 6.7413 + 0.4681 x$	(a)	$r = 0.6961$	--
	DVM	420	$Y = 7.7848 + 0.6676 x$	(b)	$r = 0.8135$	--
	SOW	420	$\log Y = -5.1661 + 2.2373 \log x$	(c)	$r = 0.7983$	--
	FW	420	$\log Y = -5.9275 + 1.8418 \log x$	(d)	$r = 0.7253$	No
	DW	420	$\log Y = -8.3942 + 1.9877 \log x$	(e)	$r = 0.6195$	No
IV	DEPTH	200	$Y = 0.5546 + 0.6320 x$	(a)	$r = 0.9459$	--
	DVM	200	$Y = 3.4123 + 0.7888 x$	(b)	$r = 0.9611$	--
	SOW	200	$\log Y = -6.5502 + 2.6461 \log x$	(c)	$r = 0.9700$	
	FW	200	$\log Y = -6.1034 + 2.0821 \log x$	(d)	$r = 0.8139$	No
	DW	200	$\log Y = -8.2519 + 1.9942 \log x$	(e)	$r = 0.6563$	No
V	DEPTH	520	$Y = 6.0683 + 0.5131 x$	(a)	$r = 0.6088$	--
	DVM	520	$Y = 9.3565 + 0.6332 x$	(b)	$r = 0.8231$	--
	SOW	520	$\log Y = -4.43506 + 2.0601 \log x$	(c)	$r = 0.7743$	No
	FW	520	$\log Y = -6.7078 + 2.1296 \log x$	(d)	$r = 0.6981$	No
	DW	520	$\log Y = -6.4473 + 1.5701 \log x$	(e)	$r = 0.4291$	No
VI	DEPTH	190	$Y = -2.1928 + 0.6791 x$	(a)	$r = 0.9643$	--
	DVM	190	$Y = 0.8586 + 0.8882 x$	(b)	$r = 0.9730$	
	SOW	190	$\log Y = -7.7004 + 2.9621 \log x$	(c)	$r = 0.9706$	Yes
	FW	190	$\log Y = -6.8499 + 2.1909 \log x$	(d)	$r = 0.8671$	No
	DW	190	$\log Y = -15.9498 + 4.3100 \log x$	(e)	$r = 0.9081$	No

MORPHOMETRIC RELATIONSHIP - STATION 2

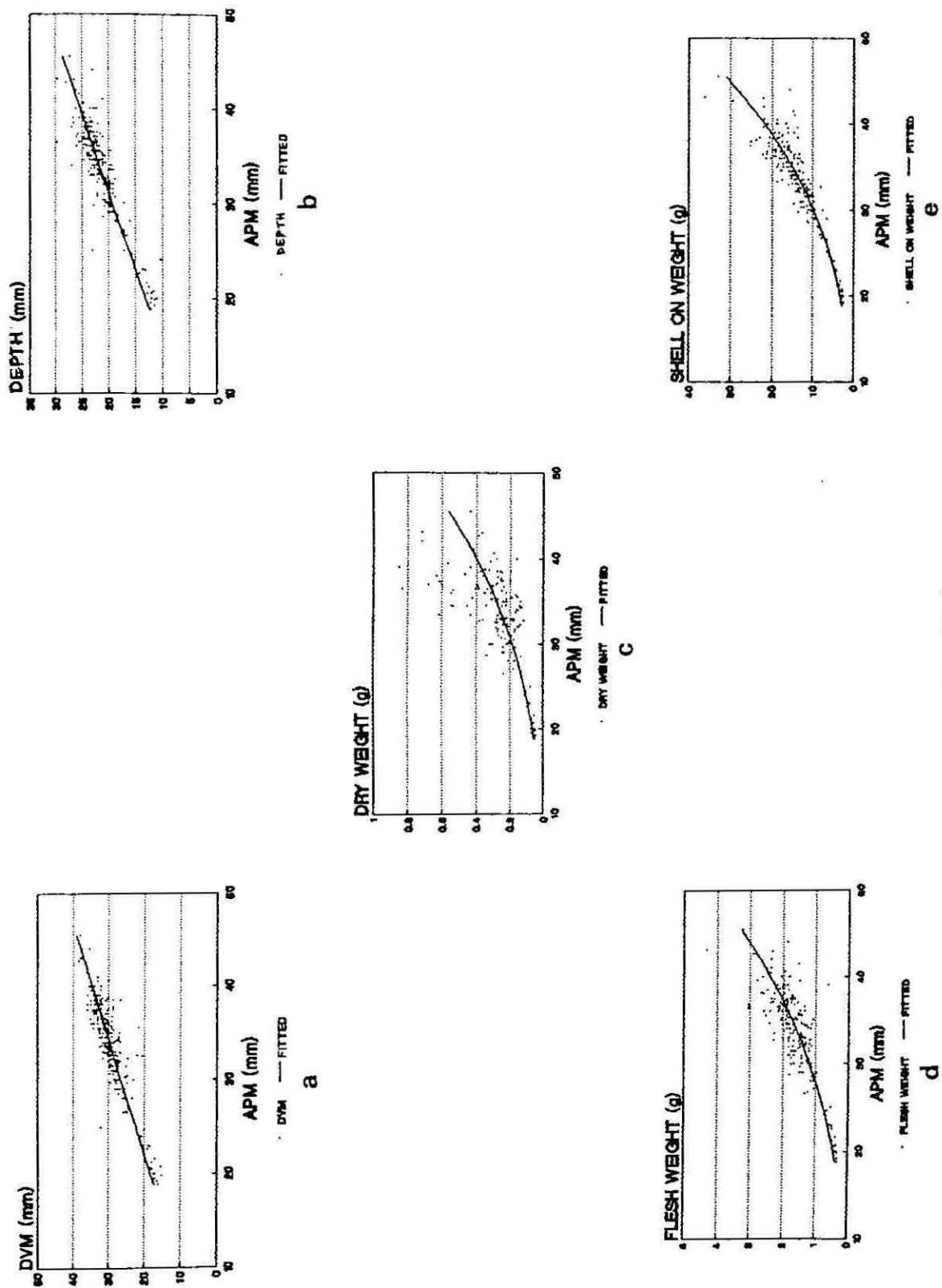


Fig.32.1

MORPHOMETRIC RELATIONSHIP - STATION 3

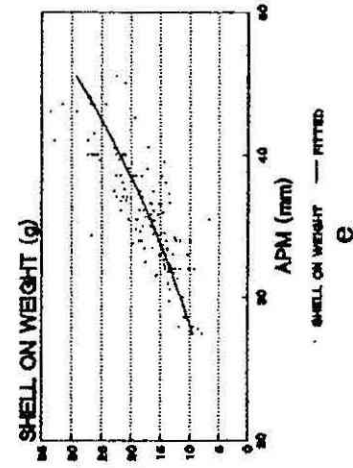
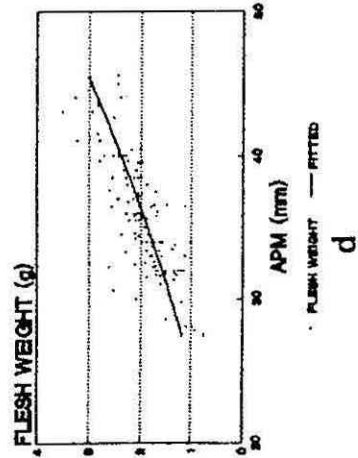
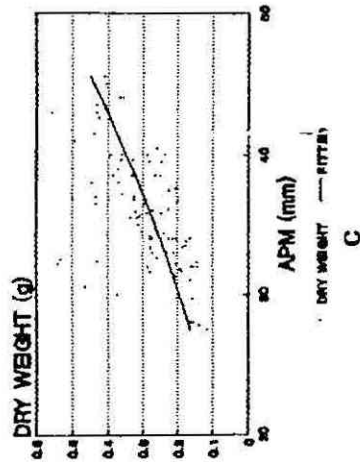
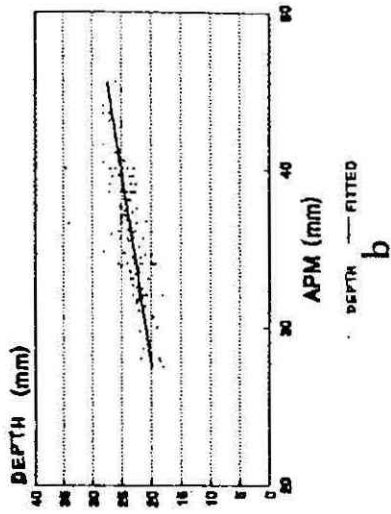
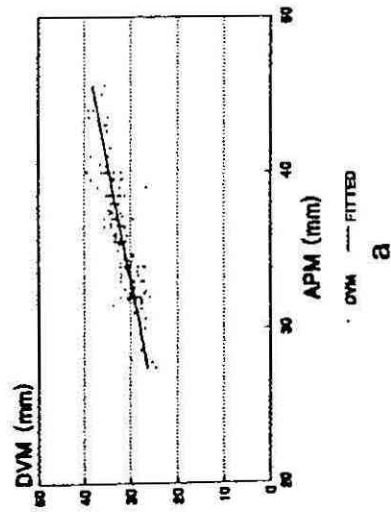
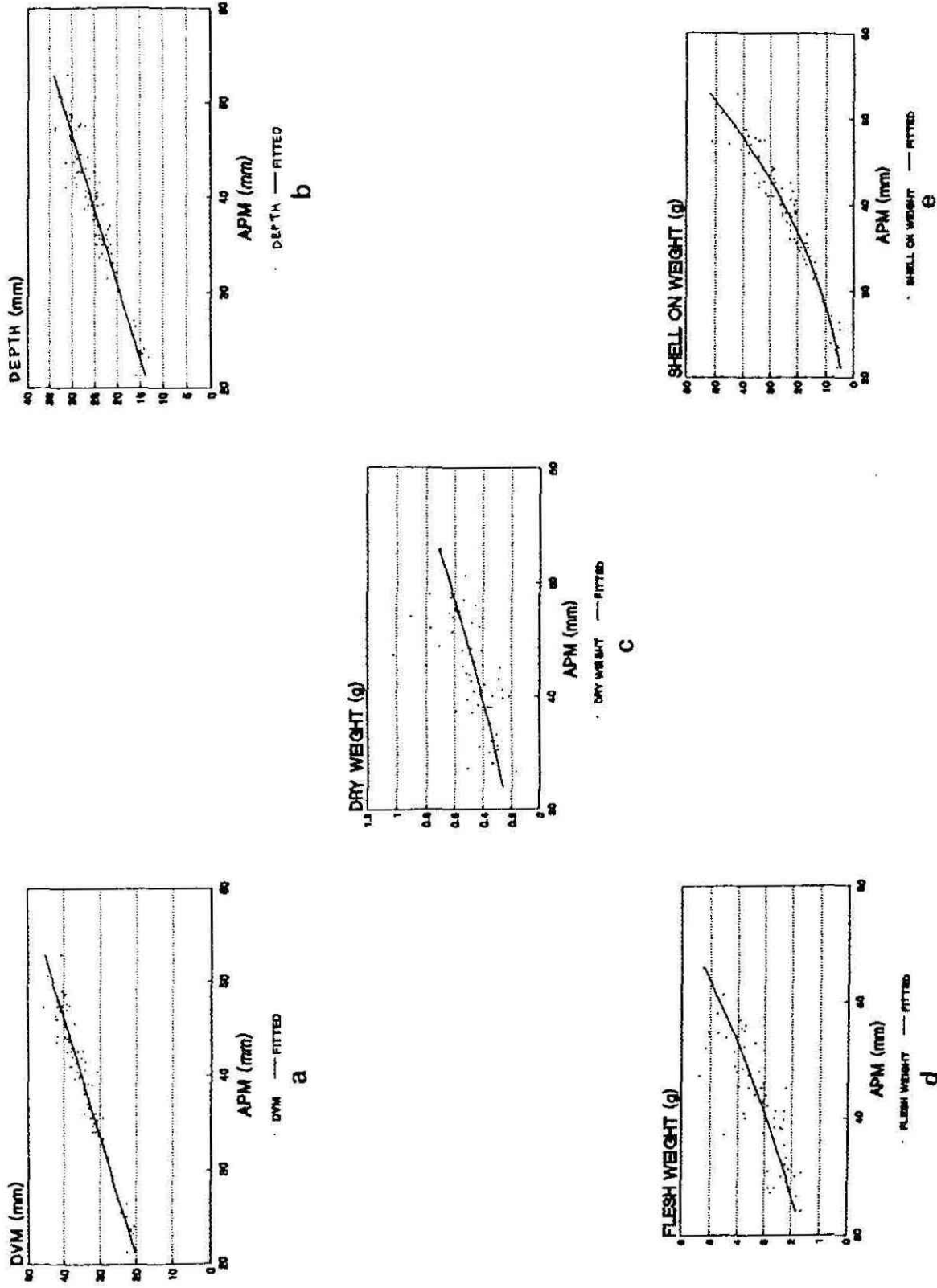


Fig.32.2

MORPHOMETRIC RELATIONSHIP - STATION 4



.Fig.32.3

MORPHOMETRIC RELATIONSHIP - STATION 5

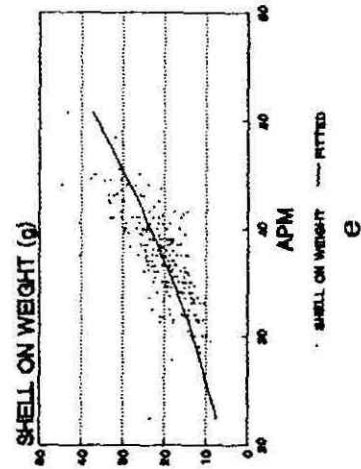
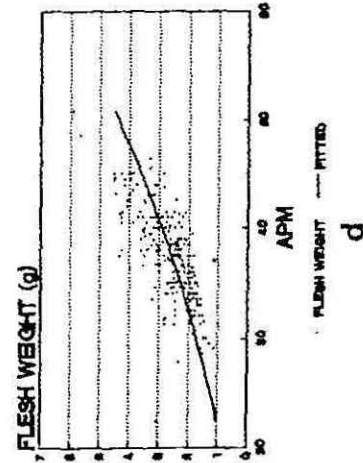
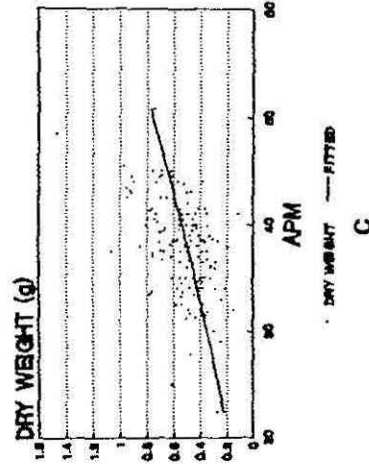
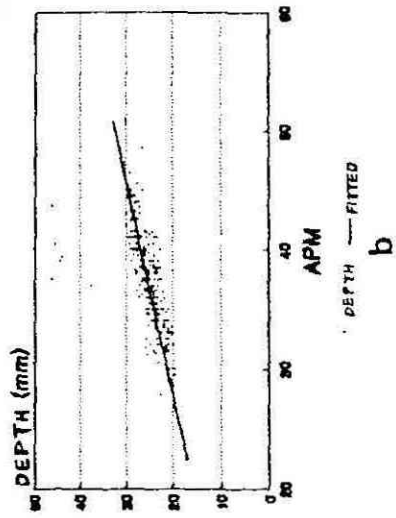
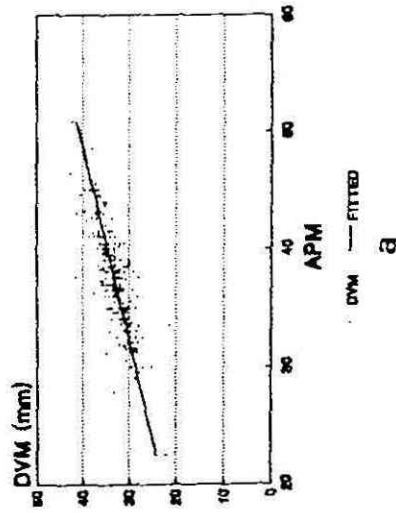


Fig.32.4

MORPHOMETRIC RELATIONSHIP - STATION 6

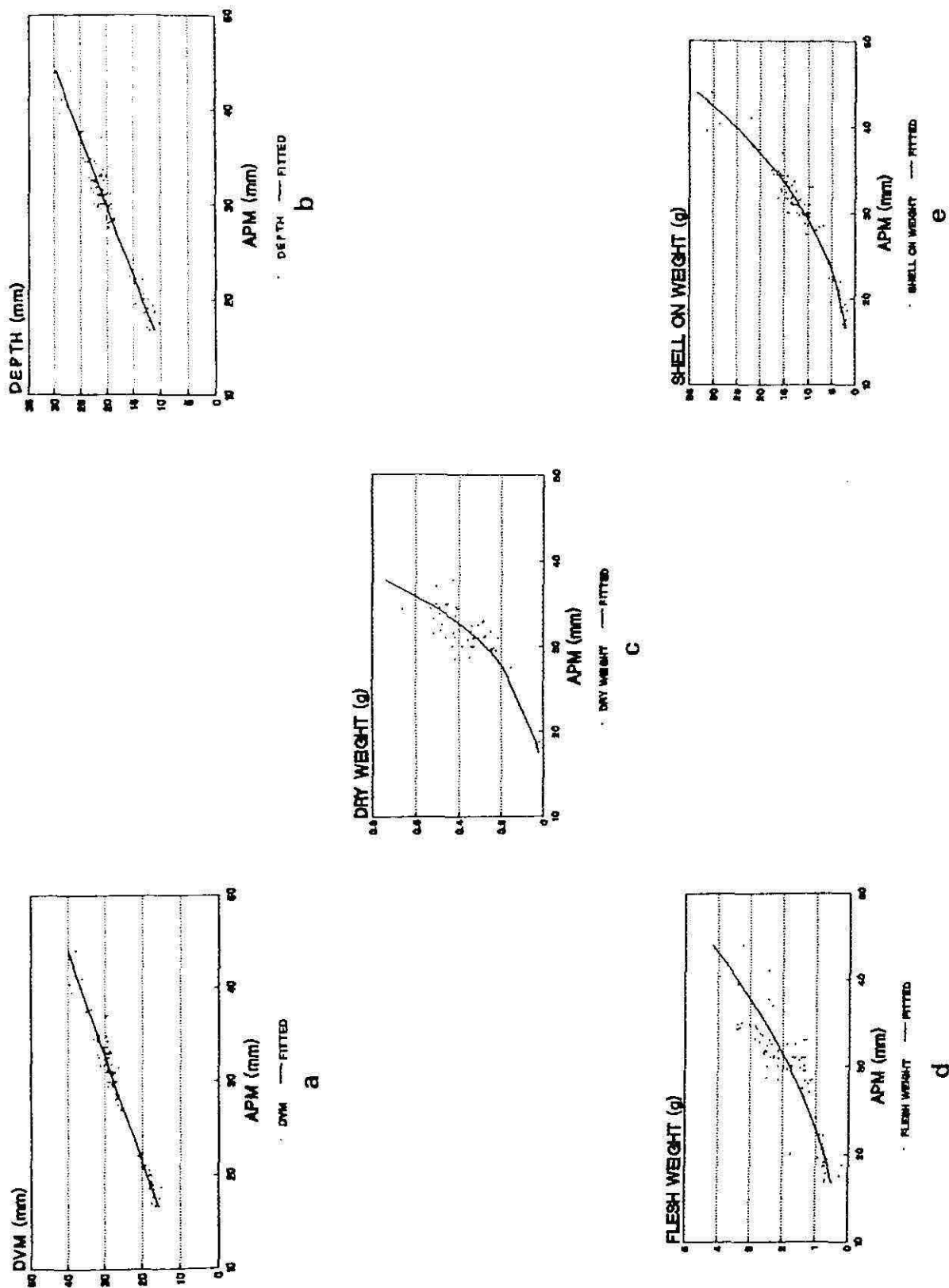


Fig.32.5

and 'r' values from 0.6981 to 0.8782. In the case of length-dry weight, the 'b' values ranged from 0.4291 to 0.9081. Thus the 'b' values, in general are not close to 3, except in the case of length-shell on weight equation for Station VI, indicating that the length-weight relationships are allometric. But 'b' values in the equation APM-SOW, do tend close to 3 when compared to the other two regressions.

The results of the 't' test carried out for significance of 'b' values indicated that these values were significantly different from '3' for the various length-weight relationships except in Station VI (APM-SOW).

3.6 Observations on Gonadal Activity

The percentage occurrence of clams in different maturity stages is listed in Table 12. The gonadal smears observed during the months of April and May indicated the occurrence of maturing and ripe clams in Stations II, III and V with the latter group dominating in May. All the stations recorded only spent animals in July. At Stations II and III spent clams continued to occur in large numbers even in the during August and September, where as at Stations IV, V and VI, increased occurrence of claims in the maturing stage.

3.7 Observations on condition index (C.I)

The C.I. values for the individual clams during the study period were found to vary between 9 and 30 with an average of 13.70. In a given month

STN	MATURITY STAGE	MONTHS						
		APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
II	MATURING	60	10	--	--	--	10	15
	RIPE	20	30	5	--	--	--	--
	PARTIALLY SPAWNED	5	35	25	--	--	--	--
	SPENT	15	25	70	100	100	90	85
III	MATURING	70	10	--	--	--	5	5
	RIPE	10	25	20	--	--	--	--
	PARTIALLY SPAWNED	10	40	15	--	--	--	--
	SPENT	10	25	65	100	100	95	95
IV	MATURING	--	--	--	--	20	25	40
	RIPE	--	--	--	--	--	--	--
	PARTIALLY SPAWNED	--	--	--	--	10	00	--
	SPENT	--	--	--	--	70	75	60
V	MATURING	--	--	--	--	30	80	80
	RIPE	10	--	--	--	--	--	5
	PARTIALLY SPAWNED	50	30	--	--	--	--	--
	SPENT	40	70	100	100	70	20	15
VI	MATURING	50	10	--	--	20	50	90
	RIPE	10	50	10	--	--	--	10
	PARTIALLY SPAWNED	10	--	30	--	--	--	--
	SPENT	30	40	60	100	70	20	15

TABLE:12PERCENTAGE OF CLAMS IN DIFFERENT MATURITY STAGES.

the C.I. values varied significantly between size classes (Fig.33). The pooled averages for all stations in each month and the ranges of C.I. values for each size class (5 mm class) are given in Table 13. In April-June average C.I. values were moderate around 13. There was fall in C.I. in July 10.93. In August C.I. improved to 13.69 and during September and October, high C.I. values of over 16 were recorded.

In general, C.I. values were relatively high in the clams ranging from 20-35 mm during April-June period, and of these, 20-25 mm group showed better values in April. While the 25-35 mm size classes showed better values in all the 3 months. In the 35-50 mm size class the C.I. values improved during post monsoon months (September-October). This trend was also showed by the 30-35 size class in the post monsoon months. Thus the clams of 20-30 mm showed better condition during premonsoon and 30-50 mm, during the post monsoon months, while, in general, all size classes exhibited poor condition during July.

Station II

The range of C.I. in April, May and June was 10-16 with an average of 12.36; the 26-34 mm class had values between 12 and 16; 35 mm class had values less than 12; further 30-34 mm size exhibited a fall in July, but for 35 mm, it remained steady at 12. During August-September the smaller ones began to show improved values while the larger clams showed reduced

TABLE 13. MONTHLY CONDITION INDEX VALUES AND CONDITION INDEX VALUES FOR DIFFERENT SIZE CLASSES (20mm - 50mm at 5mm intervals) OVER SEVEN MONTHS

MONTH	AVERAGE C.I. FOR MONTHS	TOTAL AVERAGE C.I.	C.I. FOR SIZE CLASSES		
			20-25mm	25-30mm	30-35mm
APRIL	13.21	13.70	32-16.5	13.5-16.5	11.5-13.5
MAY	12.22		13.13.5	13-13.7	13.2-11.8
JUNE	13.57		13.7-15.5	14.7-16.1	13.3-14.7
JULY	10.93		10.9-11.2	11-9.5	10.2-11.9
AUGUST	13.69		10.7-13.4	10.2-14.5	13.5-14.5
SEPTEMBER	16.095		11-12.5	11.5-13.3	16-17.2
OCTOBER	16.15		12-12.5	13-15.1	14.3-20.8
					13.5-17.5

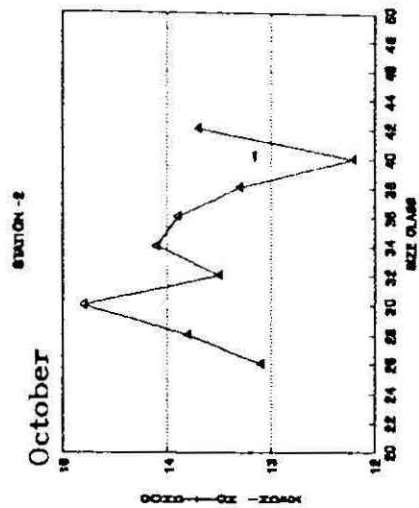


Fig.33.1f

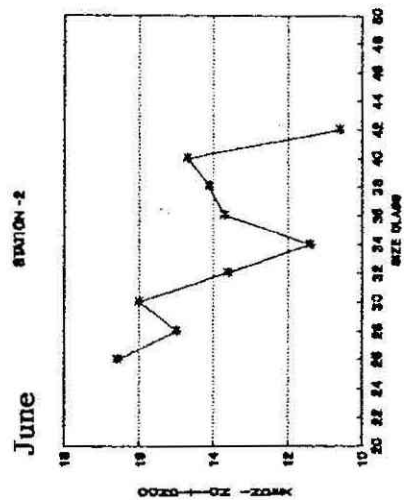


Fig.33.1c

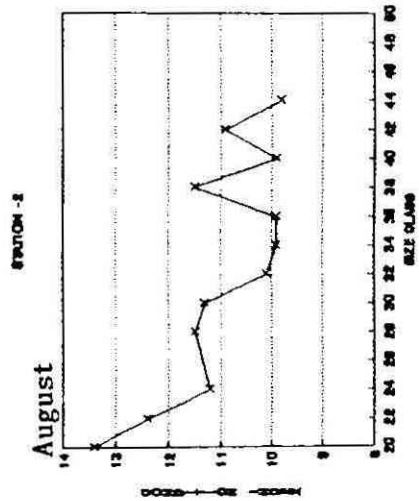


Fig.33.1e

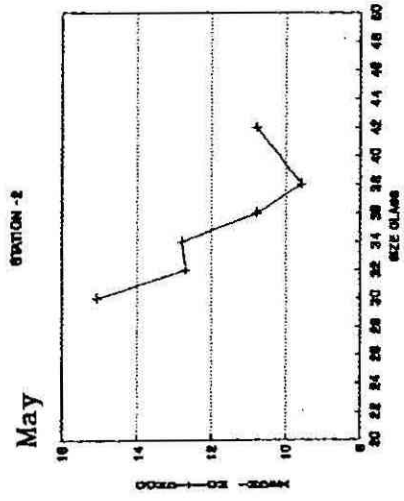


Fig.33.1b

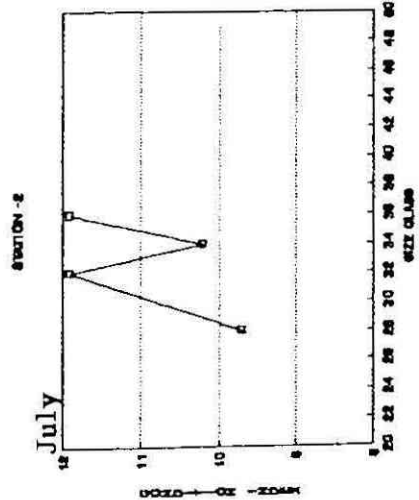


Fig.33.1d

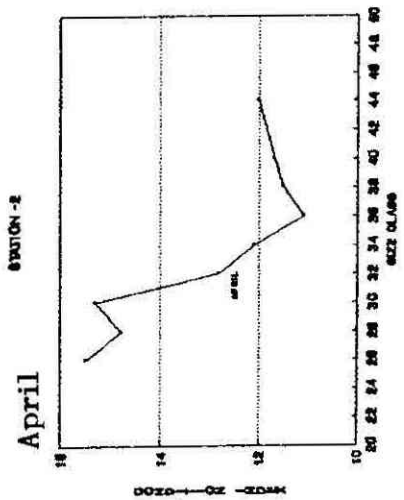


Fig.33.1a

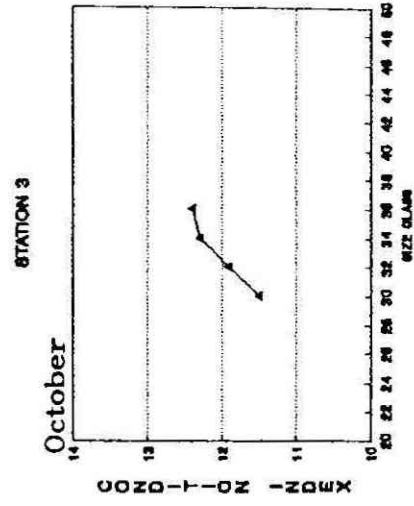


Fig. 33.2d

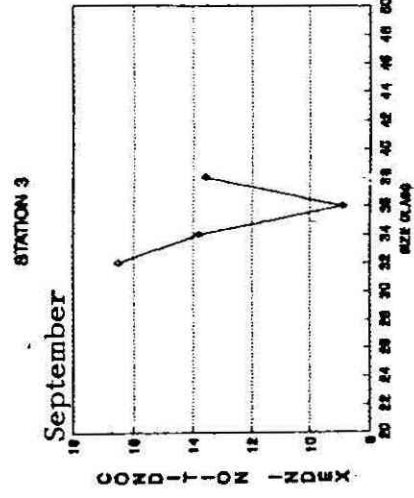


Fig. 33.2e

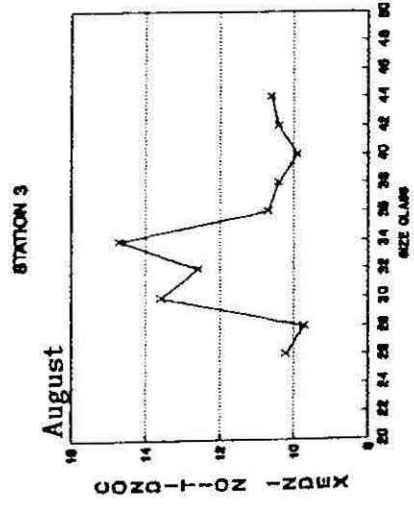


Fig. 33.2f

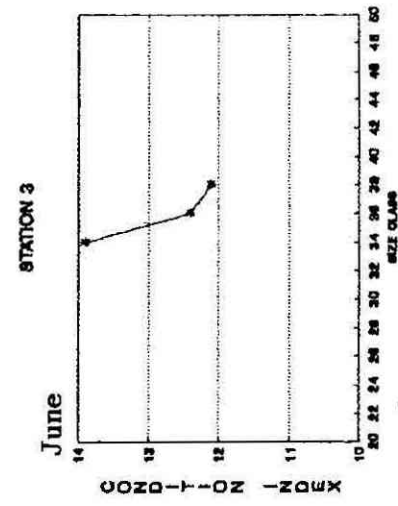


Fig. 33.2a

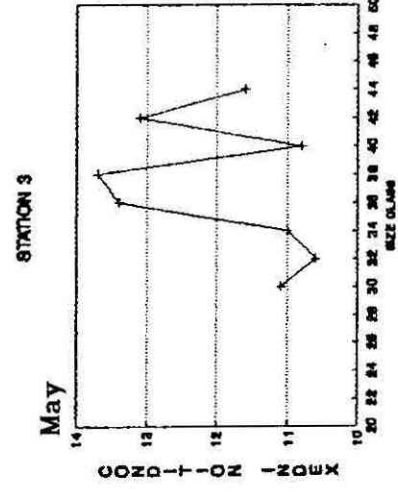


Fig. 33.2b

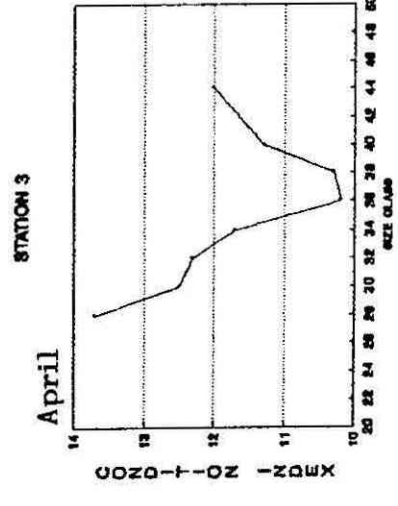


Fig. 33.2c

STATION - 5

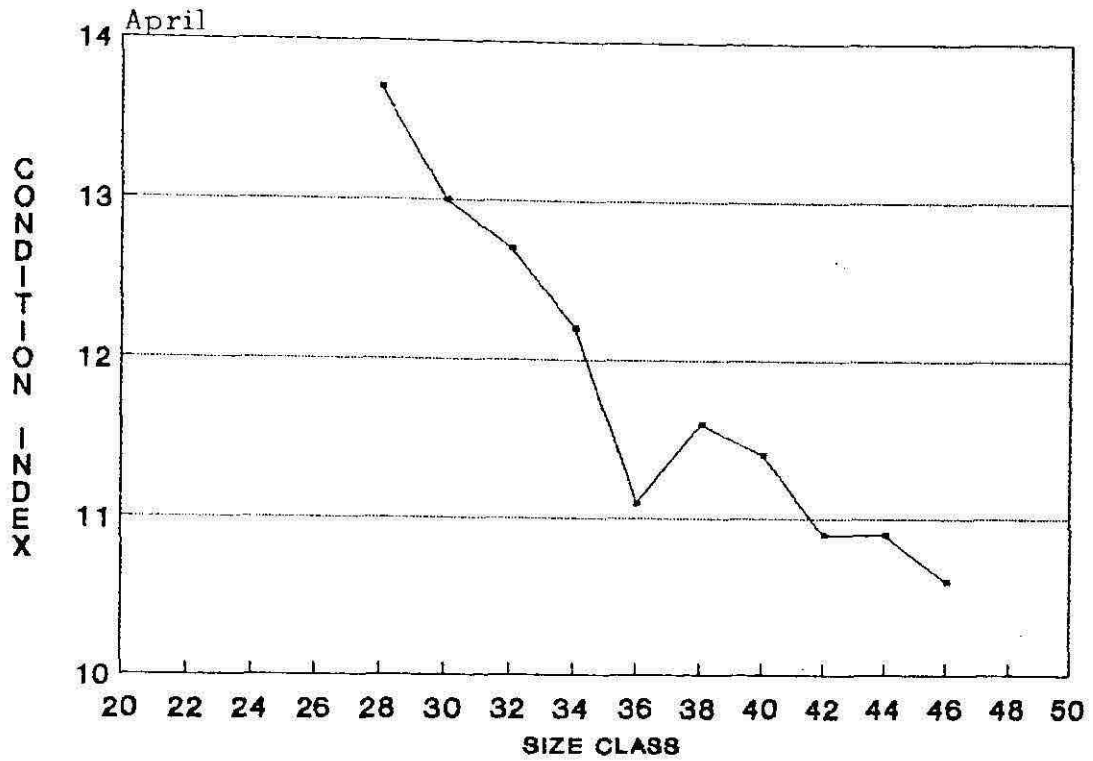


Fig.33.3a

STATION - 5

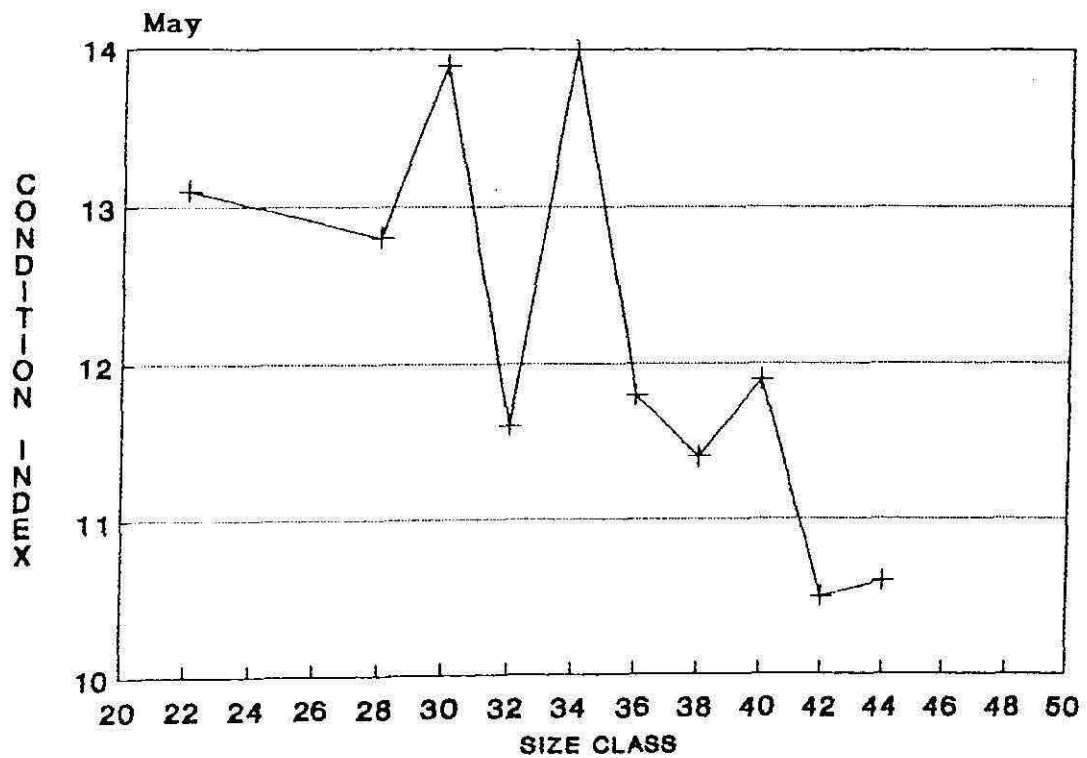


Fig.33.3b

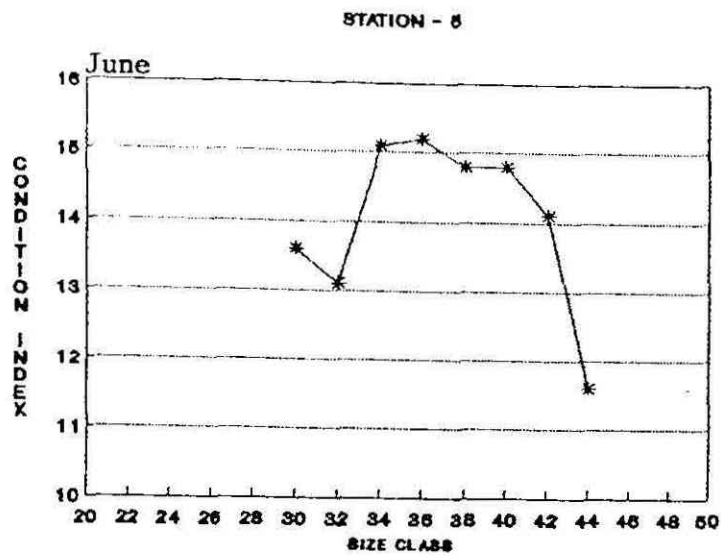


Fig.33.3c

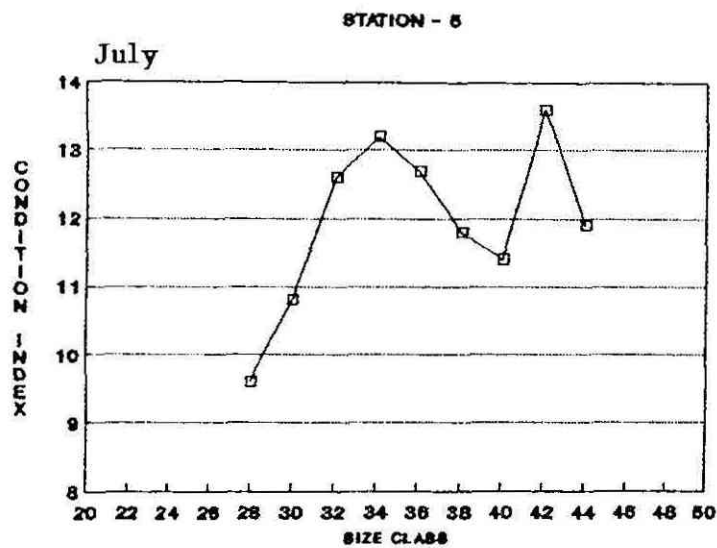


Fig.33.3d

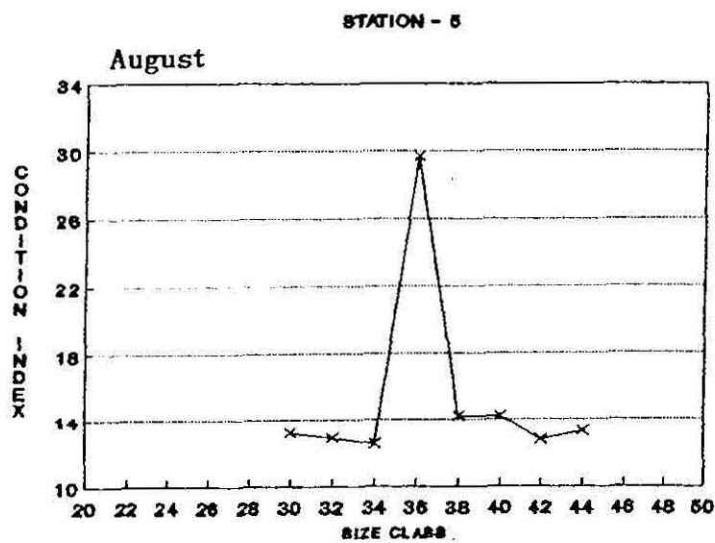


Fig.33.3e

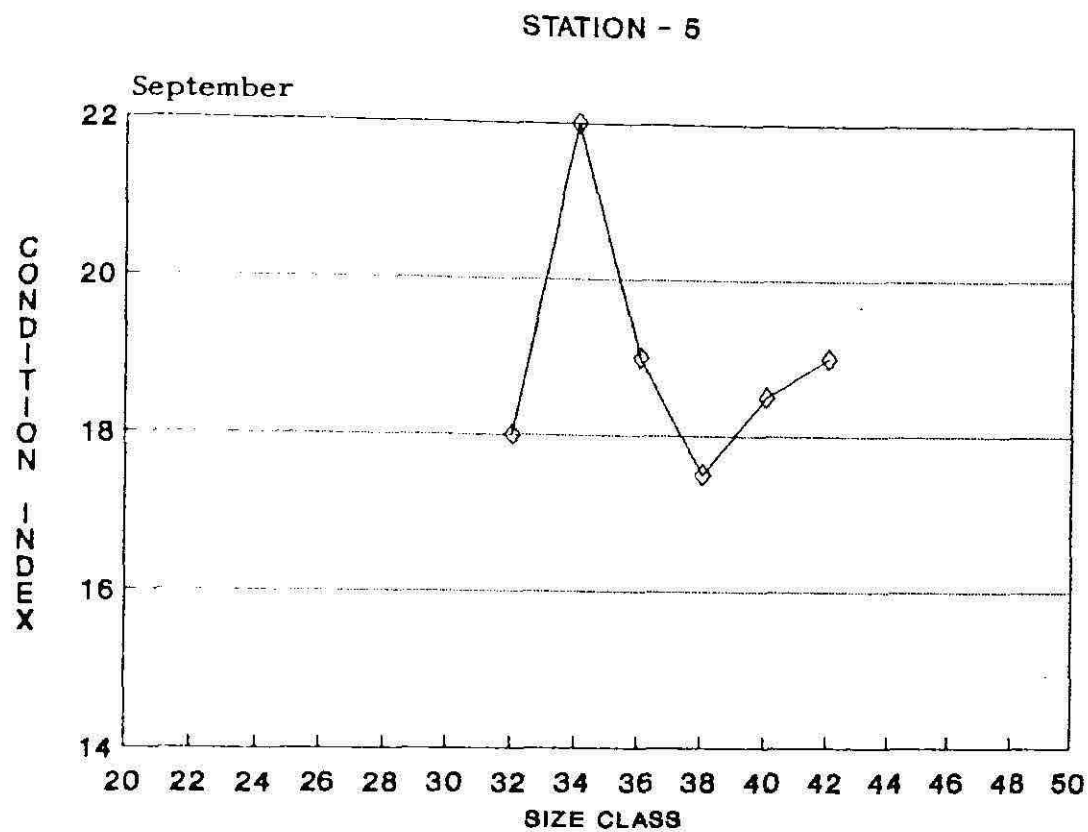


Fig.33.3f

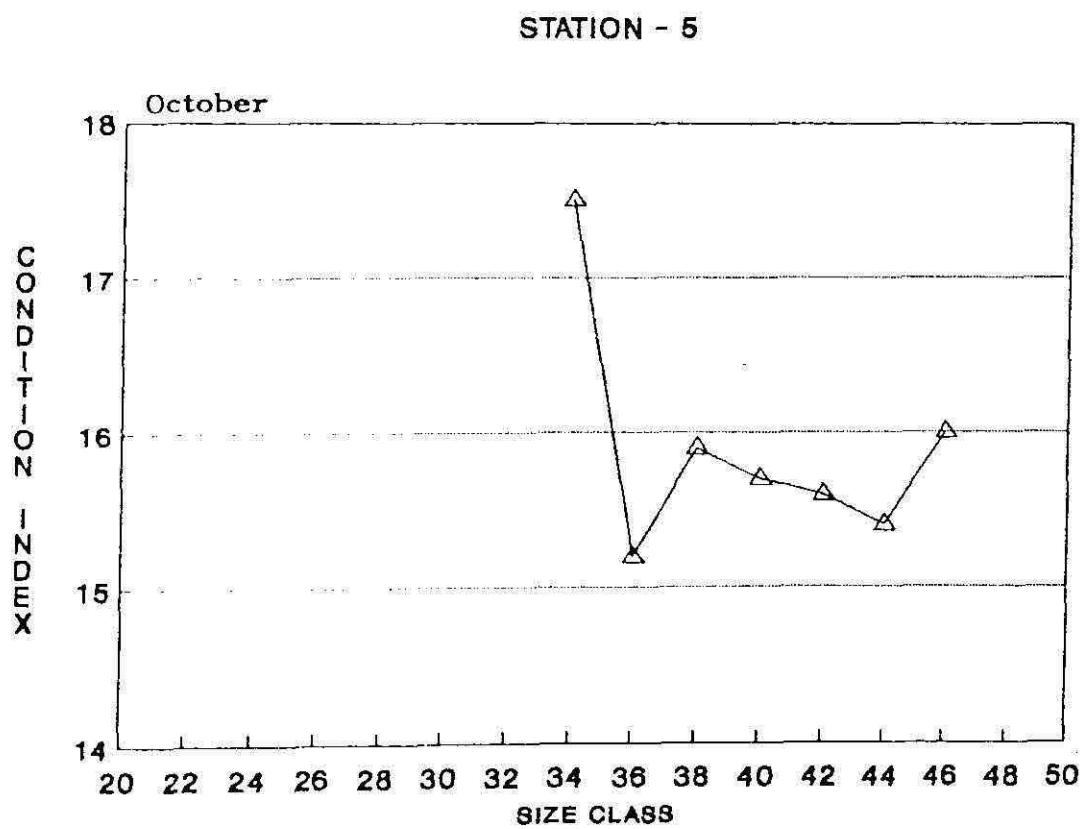


Fig.33.3g

STATION 4

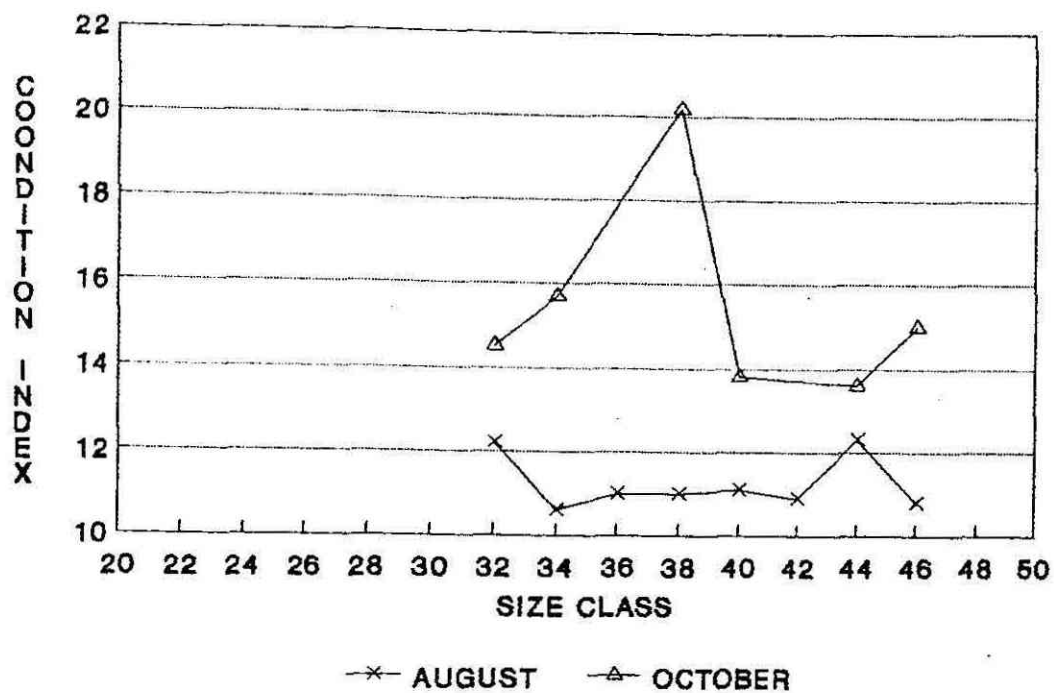


Fig.33.4

STATION - 6

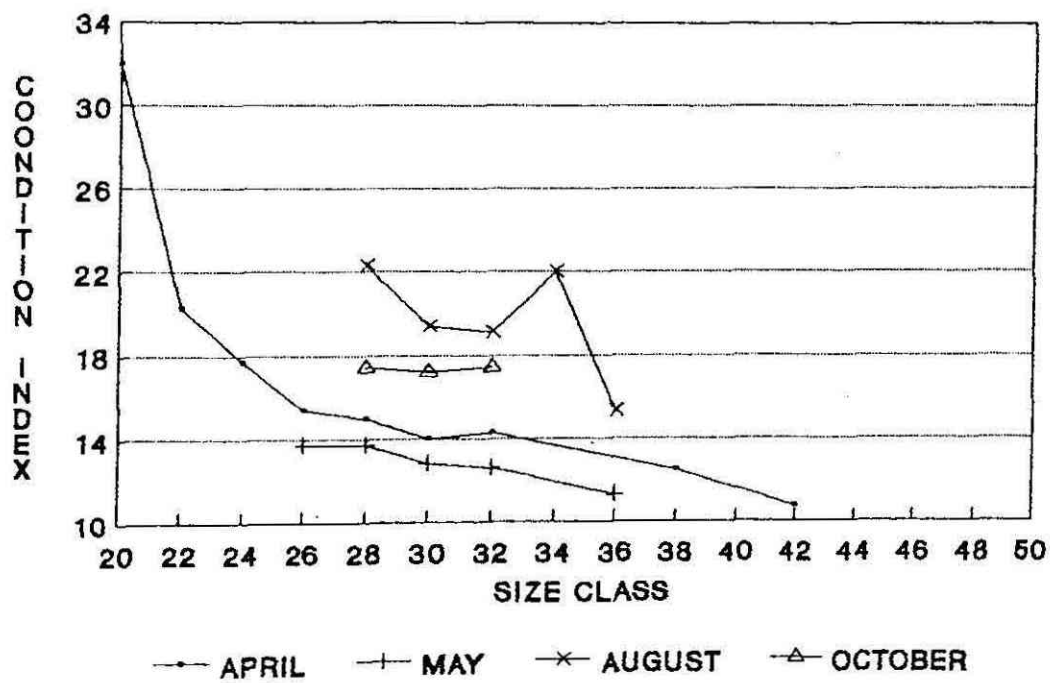


Fig.33.5

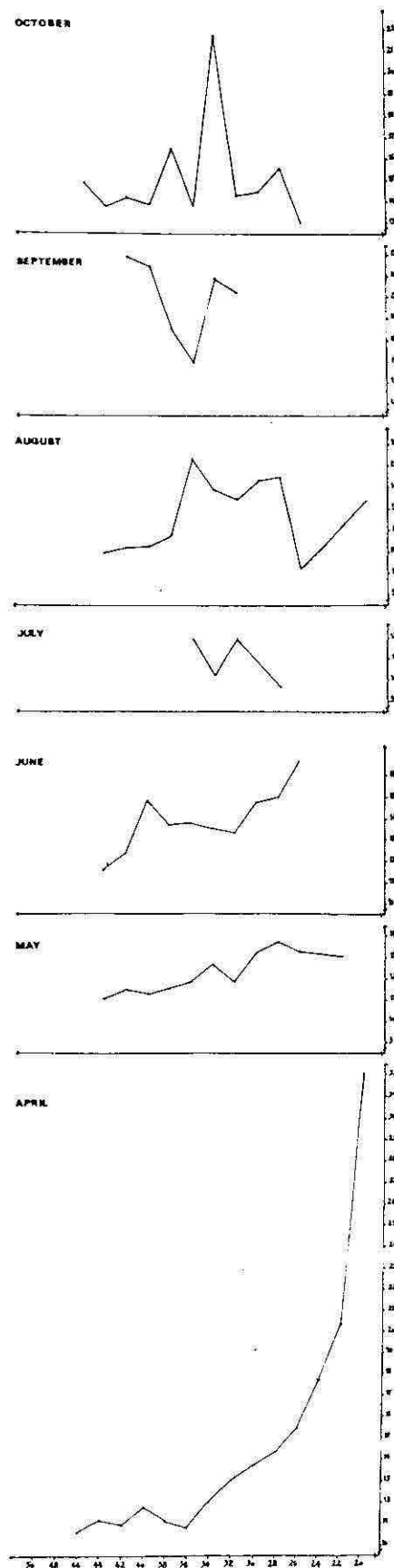


Fig. 33.6 Monthly trend in Condition Index of different size groups.

conditions indices. It is significant to note that by October, the C.I. values of all the size groups of clams were more or less comparable.

Station III

The C.I. ranged from 8-18 with an average of 12.15; 20-35 mm group showed consistent increasing trend from April to June followed by a reduction to very low levels in July and August. The 35 mm size showed steady values during this three months period (April-June), followed by a gradual, though small, improvement.

Station IV

The clams were collected only during August and October and the condition ranged between 10 and 20 with an average of 13.35; the 30-46 mm size classes showed an improvement from 10 to 12 by August to 14-20 in October. Clams in the 30-35 mm length range showed maximum condition values of 20 during October.

Station V

The C.I. values range from 10 and 30 with an average of 14.71; the 28-35 mm sizes exhibited higher values in the range of 12 to 16 during April-June, which declined to 9-14 in July. The 35-46 mm class showed low C.I.

in April and May it improved in June and further increased till October. The 30-46 mm sizes showed high C.I. values of 12-30 from August onwards.

Station VI

The C.I. values ranged from 10-22 with an average of 18.22 very high values were obtained in April and August for clams measuring 20-25 mm and 28-36 mm. Decreased values were noted in May-July period while the values steadied at 15-18 in October.

3.8 Estimation of Instantaneous Mortality Rates

The calculated instantaneous monthly total mortality rates (Z) at each station are given in Table 14.

The computed total instantaneous mortality rates (Z) for all the stations based on monthly samplings are given below:

April	:	1.337
May	:	2.689
June	:	2.067
July	:	2.253
August	:	1.771
September	:	1.181
October	:	1.024

TABLE : 14 AVERAGE MONTHLY MORTALITY RATES PER STATION

Results								L'R = 8mm (class)	
								(April - October)	
								Average	
STATION	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER		
II	0.1114	0.2241	0.1797	0.1878	0.1743	0.1048	0.0883	$\frac{1.83}{12}$	= 0.1525
III	0.1115	0.09633	0.1639	0.2898	0.1159	0.1176	0.0967	$\frac{1.70}{12}$	= 0.1417
IV	-	-	-	-	0.055	0.0928	0.0862	$\frac{0.94}{12}$	= 0.0783
V	0.0358	0.0418	0.0273	0.0314	0.0359	0.0271	0.0243	$\frac{0.38}{12}$	= 0.0317
VI	0.0683	0.1409	-	-	0.0773	-	0.0465	$\frac{1}{12}$	= 0.0833

The estimated mean 'Z' value was 1.76 (SD=0.613) for the black clam population in the study area.

3.9 Observations on Spat Settlement

(1) Sampler 'A' introduced at Poothotta:

- (a) Terrestrial soil collected from Panangad: There was immense blackening of this substrate, with the formation of black muck beneath the soil. No spat was recovered from this substrate.
- (b) Granite Powder: Yield of spat from this soil too was poor (1 number/l)
- (c) Sand with manure: There was a good spatfall in this substrate; the spat count averaged at 30 nos./l of soil sample.
- (d) Sand (coarse): Very little spat was obtained from this substrate (13 nos/l).

The general ecological conditions found in this station were:

Salinity	:	0 to 1 ppt
Dissolved Oxygen	:	3.85 to 4.3 ml/l
pH of natural soil	:	4.28 - 5.10
Organic carbon	:	1.128 - 1.14%
Texture	:	% sand 84.33
		% silt 3.47
		% clay 12.20

Spat count obtained from natural sediment sampling were 100/l (live) and 300,l (dead).

Sampler B, introduced at Thykudam (Station II)

<u>Type of Substrate</u>		<u>Average spat count</u>
(a)	Soil from Station II :	45/1
(b)	Terrestrial soil from Panangad :	7/1
(c)	Sand (riverine sand) :	13/1
(d)	Sand + Manure :	23/1

Sampler C, introduced at Irimpanam, (Station I)

No settlement was observed in any of the 4 substrates used in this sampler and in the natural sediment, irrespective of their characteristics. But the deposition of silt increased considerably on the substrates.

The initial and final values of pH, texture and organic content of the substrates used in the samplers are listed in Table 15.

3.10 Salinity Tolerance Experiments

Ten days exposure of V. cyprinoides to different salinity levels gave a clear indication of the tolerance limits of the clams. The cumulative percentage mortality of large and small clams exposed to different salinities is given in Table 16.

Table 15 INITIAL AND FINAL TEXTURE, pH AND ORGANIC CONTENT VALUES OF SUBSTRATES

Substrate	pH		Organic Carbon (%)		Organic matter (%)		Organic nitrogen (%)		Sand (%)		Silt (%)		Clay (%)	
	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
Terrestrial Soil (Panangad)	3.95	3.25	1.3892	1.5672	2.3950	2.714	0.1197	0.1357	97.24	74.32	1.0	4.26	1.765	1.42
Granite Powder	7.83	4.0	0.0	0.97	0.0	1.680	0.0	0.08	95.1	94.2	3.4	4.72	1.5	1.08
Sand + Manure	7.2	5.95	2.145	2.342	3.715	4.058	0.186	0.203	93	92	2.6	4.75	4.1	3.2
Sand (riverine)	5.88	5.7	0.16	0.85	0.277	1.472	0.014	0.074	98.6	97.3	0.3	1.65	1.1	1.05
Station II Soil	5.03	5.42	0.631	0.724	1.088	1.25	0.05	0.06	91.31	90.12	0.3	1.47	8.37	8.41
Station I Soil	7.09	7.23	4.066	4.132	7.01	7.157	0.35	0.036	28.88	27.16	29.12	32.6	42.06	40.24

Particle features

1. Terrestrial soil (Panangad) - Sand (< 0.5mm) + Silt + Clay
2. Granite powder - approx. 1mm diameter
3. Sand + Manure - 70% sand (1mm - 0.5mm) + Clay mixed with decomposed dung
4. Sand (riverine) - 2mm diameter
5. Station II soil - Sand (< 0.5mm)
6. Station I soil - Very fine sand; more of silt and clay.

(a) **Responses of larger size groups (> 20 mm)**

Survival was noticed mainly in salinities ranging from 0 to 13 ppt. Maximum survival was noticed in 1 ppt (91.67%); clams exposed to 2 and 3 ppt also showed high survival rates of 86.7% and 88.3% respectively. Moderate survival rates of greater than 50% were observed in the clams at 4,5,7 10 and 13 ppt. Total mortality was noticed in all salinity levels above 17 ppt, with clams in higher salinities (21, 27 and 34.5 ppt) showing 100% mortality in just 3 days from commencement of the experiment. Though the extent of survival in 10 days in 0 ppt was considerably low at 56%, mortality increased only after the 5th day of exposure. While mortality remained almost constant at about 10% in 1, 2 and 3 ppt and approximately 30% in 4-13 ppt, sudden deaths were noticed, in higher salinities.

Analysis of variance of the experimental data showed that the mortalities at different salinities were significantly different at 1% level.

(b) **Responses of the smaller size groups (10-19 mm)**

Smaller clams exhibited a pattern of response similar to that exhibited by larger ones, during exposure to different salinities for 10 days. The clams survived only in salinity levels of 1-13 ppt. The maximum survival (98%) was obtained in 10 ppt while equally good survival rates (88-96%) were obtained in 1-9 ppt and 13 ppt gave a moderate survival of 74%. Salinities above

TABLE: 16 : PERCENTAGE MORTALITY OF LARGE AND SMALL CLAMS IN VARYING SALINITIES

DAY	0	1	2	3	4	5	7	10	13	17	21	27	34.5	
I	0	0	1.7	0	0	0	0	1.7	1.7	0	1.7	1.7	3.3	LARGE
	2	6	4	2	0	0	0	0	0	0	0	0	0	SMALL
II	0	0	1.7	0	1.7	3.33	6.7	6.7	3.3	43.3	65	35	43.3	LARGE
	2	6	6	4	0	0	0	0	0	30	76	60	76	SMALL
III	8.3	3.33	8.33	6.7	20	21.7	23.3	20	23.3	63.3	100	100	100	LARGE
	46	8	8	8	6	2	4	2	14	56	100	100	100	SMALL
IV	11.7	3.33	8.33	8.33	25	28.33	26.7	21.7	23.3	91.7	-	-	-	LARGE
	56	8	12	8	6	2	6	2	18	84	-	-	-	SMALL
V	11.7	3.33	8.33	10	25	30	26.7	23.3	26.7	100	-	-	-	LARGE
	64	8	12	8	6	2	6	2	20	90	-	-	-	SMALL
VI	30	8.33	11.7	11.7	30	33.3	28.3	25	36.7	-	-	-	-	LARGE
	76	12	12	8	6	2	6	2	24	96	-	-	-	SMALL
VII	35	8.33	13.3	11.7	30	33.3	30	25	38.3	-	-	-	-	LARGE
	80	12	12	8	6	4	6	2	26	100	-	-	-	SMALL
VIII	38.3	8.33	13.3	11.7	31.7	33.3	30	25	38.3	-	-	-	-	LARGE
	80	12	12	8	6	4	6	2	26	-	-	-	-	SMALL
IX	38.3	8.33	13.3	11.7	33.3	33.3	31.7	25	38.3	-	-	-	-	LARGE
	80	12	12	8	6	4	6	2	26	-	-	-	-	SMALL
X	56.7	8.33	13.3	11.7	33.3	35	31.7	25	38.3	-	-	-	-	LARGE
	98	12	12	8	6	4	6	2	26	-	-	-	-	SMALL

this level gave 100% mortality. While gradual mortality for 4 days in 0 ppt was followed by a complete fall in survival, 12% and 8% mortalities were obtained in 1 and 2 ppt.

Responses of mantle fluid to varying external salinities:

Table 17 - Summarises the variations in mantle fluid salinity in response to varying medium salinities over a period of ten days and Fig. 34 represents the trend of variation in large and small clams.

The larger clams acclimatised at 1 ppt and subjected to 0, 1 and 2 ppt external media salinity, responded uniformly for 10 days with considerably greater mantle fluid salinities than the external media salinities to which they were subjected. However, at 2 ppt medium the difference has narrowed. From 3 ppt medium onwards, the mantle fluid salinity was maintained at a lower level considerably through out the 10 days except for the 10th day in 3 ppt, where a slight increase in fluid salinity was noticed. From 3 ppt to 7 ppt medium salinity, the mantle fluid responses were almost similar, with decreased salinity level of the fluid than the media. While in the media salinity greater than 7 ppt, the initial responses in the mantle fluid salinity were nearer to the media salinity but the gap was wide. This gap was observed to increase in the media salinities ie. from 2.562 in 10 ppt to 18.91 in 27 ppt on the first day. However in 34.5 ppt medium salinity, the gap was lower at 15.25 on the first day itself; by second day, these gaps get further narrowed, for eg. in 10 ppt it was 0.375 and in 27 ppt, 11.03. The gap

TABLE : 17 MANTLE FLUID SALINITY IN VARYING MEDIUM SALINITY

Day	0	1	2	3	4	5	7	10	13	17	21	27	34.5	
I	0.6563	1.619	2.188	2.63	3.500	5.031	6.563	7.4375	8.75	5.25	3.938	8.094	19.25	Large
	0.875	2.188	3.938	7.875	6.563	8.750	7.00	8.75	17.5	5.25	15.75	8.75	16.188	Small
II	0.875	1.75	2.188	2.625	3.281	4.55	6.30	9.625	12.250	12.688	13.300	15.969	24.938	Large
	2.188	2.188	4.375	6.563	4.375	4.38	8.750	13.125	15.313	17.5	20.125	24.063	37.188	Small
III	0.875	1.313	2.406	2.625	2.844	4.156	6.563	9.188	11.813	14.438	-	12.250	-	Large
	2.1875	2.1875	4.375	2.1875	4.375	6.563	4.375	13.125	13.125	17.5	-	-	-	Small
IV	1.313	1.531	2.188	2.406	3.938	1.838	6.563	8.750	9.625	16.625	-	-	-	Large
	2.188	3.063	3.063	5.250	5.250	4.375	9.625	12.250	13.125	21.875	-	-	-	Small
V	0.481	1.750	2.450	3.413	3.675	4.813	6.125	9.625	12.688	-	-	-	-	Large
	0.875	2.188	2.625	3.500	4.375	4.813	8.75	13.125	15.313	-	-	-	-	Small

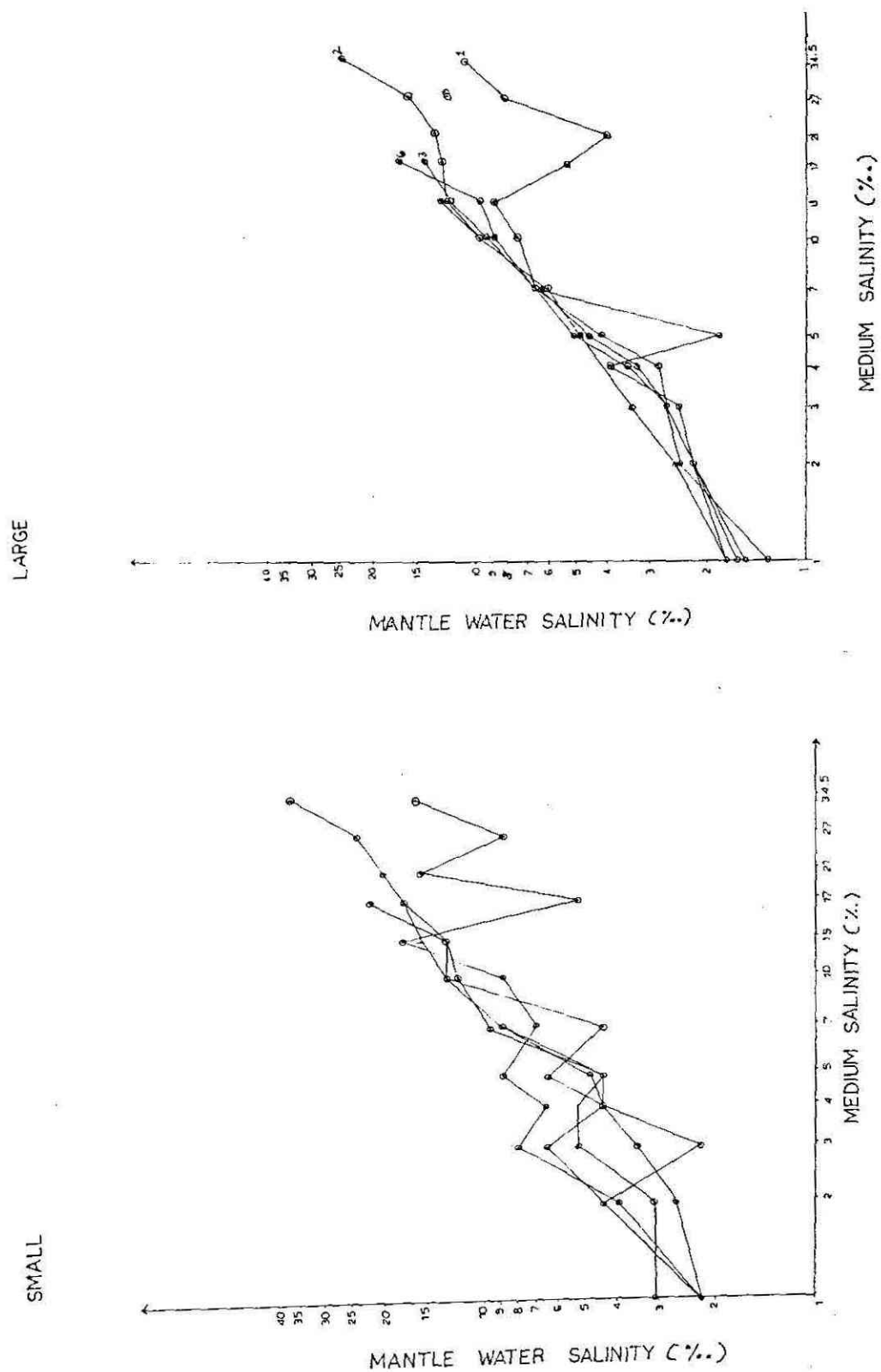


Fig.34 MANTLE WATER SALINITY OF CLAMS IN RELATION TO MEDIUM SALINITY

continued to narrow down in the clams subjected to 10, 13 and 17 ppt in the following days. The stress in greater salinities (21, 27 and 34.5 ppt) was high enough to result in 100% mortality on the 3rd day.

Comparable results were obtained when the osmolality values were studied for their respective osmotic treatments (Table 18; Figs. 35 and 36). Here in the 0-13 ppt range the mantle fluid osmotic pressures of the large clams were maintained at considerably higher levels than the media osmotic pressures; in the case of 17 to 34.5 ppt the responses were erratic on the first day as observed in mantle fluid salinity study, the mantle fluid values were considerably lower than the external media values. In the following days also the pattern conforms to what was observed in the case of the observation made on mantle fluid salinities.

The smaller clams acclimatised at 1 ppt when subjected to 0, 1, 2, 3, 4 and 5 ppt media salinities, the first days response was an appreciable increase in the mantle fluid salinity over the external media, for eg. in 0 ppt mantle fluid salinity increased to 0.875 and in 5 ppt to 3.25, but in the case of 5 ppt treatment, the mantle fluid salinity drops gradually to finally reach 4.813 ppt and in the remaining treatments the clams maintained higher salinity levels in their mantle fluids upto 10 days. The gap between media salinity and mantle salinity decreased from 1 ppt to 4 ppt treatments. In the 7 ppt treatment on the first day mantle and media salinity values were identical; henceforth the gap increased gradually and finally reached a high level than the media (gap 1.75 ppt). In the 10 ppt treatment, except for

TABLE: 18 MANTLE FLUID OSMOLALITY IN VARYING MEDIUM OSMOLALITY

Salinity Day	0	1	2	3	4	5	7	10	13	17	21	27	34.5	
I	0.031	0.069	0.087	0.102	0.127	0.157	0.216	0.251	0.277	0.108	0.08	0.262	0.563	Large
	0.031	0.108	0.18	0.171	0.171	0.487	0.362	0.565	0.636	0.559	0.593	0.25	0.908	Small
II	0.031	0.68	0.80	0.104	0.131	0.744	0.218	0.3	0.398	0.341	0.426	0.499	0.846	Large
	0.052	0.114	0.176	0.277	0.214	0.173	0.519	0.453	0.524	0.698	0.265	0.3	0.233	Small
III	0.043	0.087	0.098	0.121	0.145	0.172	0.248	0.381	0.431	0.543	-	0.53	-	Large
	0.040	0.158	0.055	0.298	0.19	0.39	0.48	1.006	0.5	1.151	-	-	-	Small
IV	0.042	0.068	0.082	0.089	0.131	0.081	0.241	0.307	0.319	0.518	-	-	-	Large
	0.047	0.167	0.151	0.135	0.19	0.148	0.307	0.296	0.5	0.965	-	-	-	Small
V.	0.027	0.063	0.076	0.103	0.131	0.160	0.233	0.311	0.404	-	-	-	-	Large
	0.039	0.102	0.125	0.138	0.177	0.219	0.272	0.37	0.496	-	-	-	-	Small

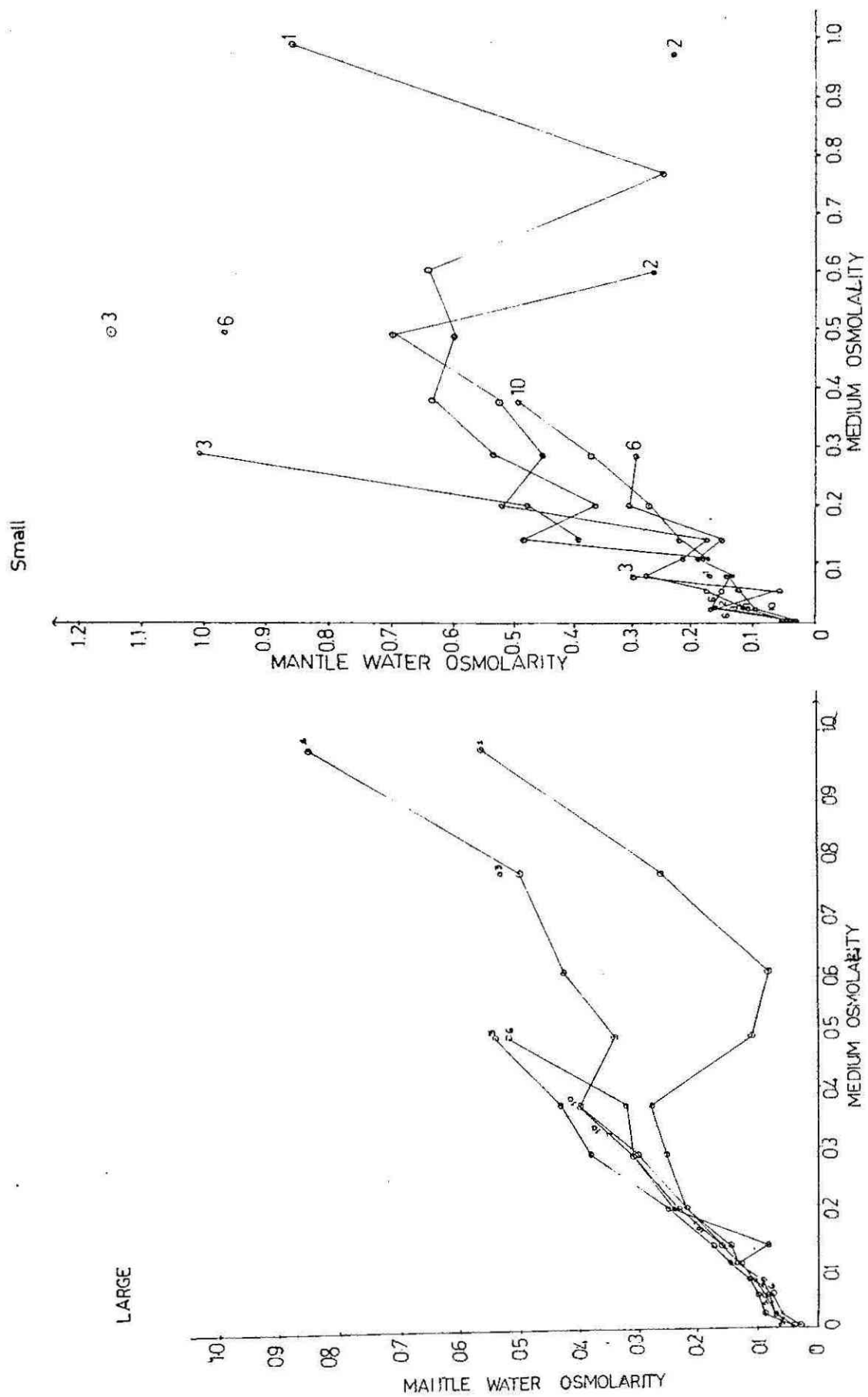


Fig.35 MANTLE WATER OSMOLALITY OF CLAMS IN RELATION TO MEDIUM OSMOLALITY

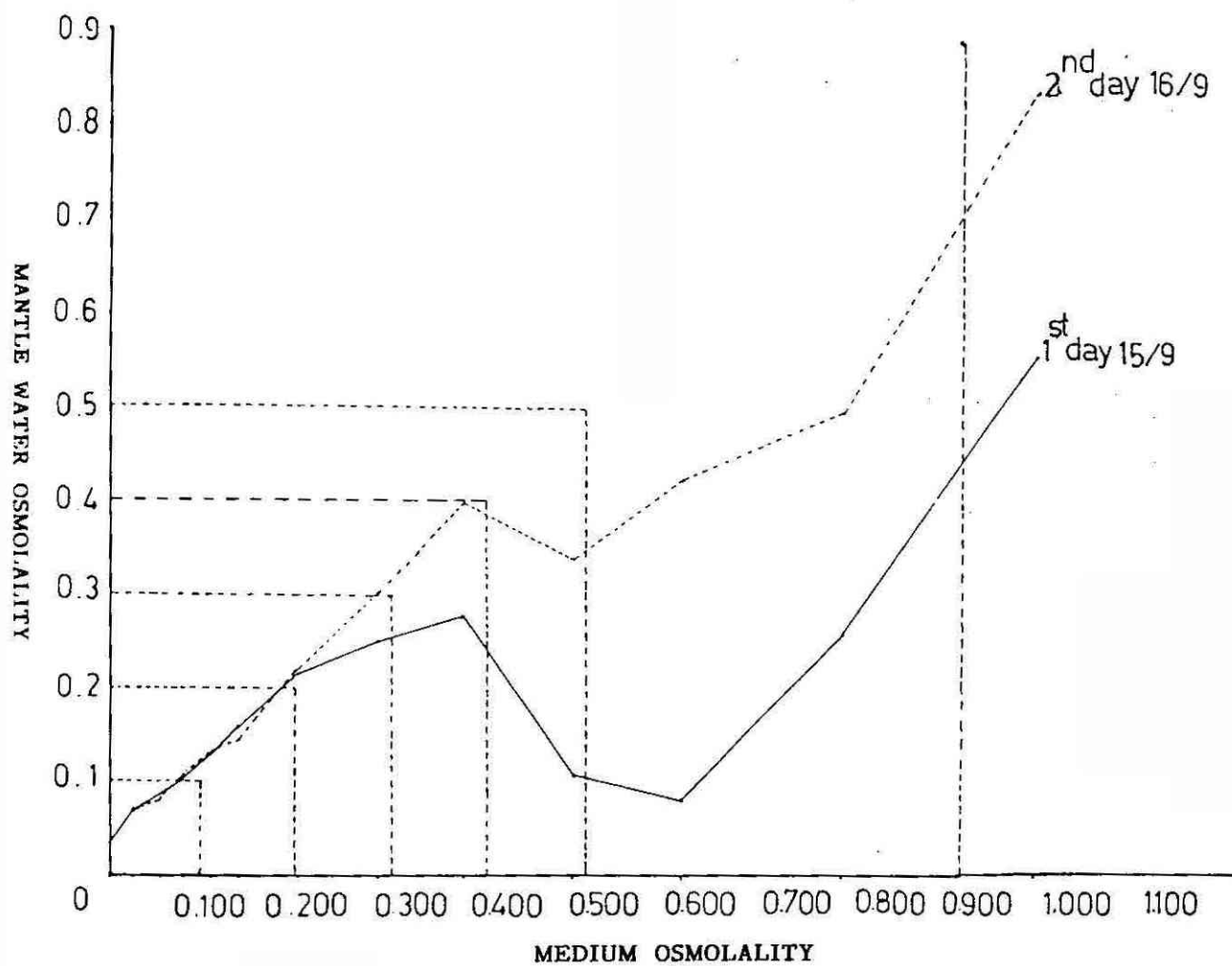


Fig.36 INCREASE IN MANTLE FLUID OSMOLALITY INDICATING ANIMAL RESPONSE

TABLE:19 RESPONSE OF MANTLE FLUID OF SURVIVING ANIMALS TO EXTERNAL SALINITY / OSMOLALITY

MEDIUM SALINITY()	0	1	2	3	4	5	7	10	13
CORRESPONDING MEDIUM OSMOLALITY (m Osm/kg)	0.005	0.024	0.055	0.081	0.111	0.140	0.202	0.285	0.376
MANTLE WATER SALINITY () (small)	0.875	2.188	2.625	3.500	4.375	4.813	8.75	13.125	15.313
MANTLE WATER SALINITY () (Large)	0.481	1.75	2.45	3.41	3.675	4.813	6.125	9.625	12.688
MANTLE WATER OSMOLALITY (Mosm/kg) (small)	0.039	0.102	0.125	0.138	0.177	0.219	0.272	0.370	0.496
MANTLE WATER OSMOLALITY (mosm/kg) (Large)	0.027	0.063	0.076	0.103	0.131	0.160	0.233	0.311	0.404

the first day (9.625 ppt) the mantle fluid salinities remained steady between 12.688 to 13.125 ppt in the following days. In the 13 ppt, the response on the first day was higher mantle salinity and the following days it varied between 13.125 to 15.313 ppt, but from 17 ppt onwards, the behaviour was different with the values closing and regulating on the first day itself with very low mantle salinities. But in the following days the mantle salinities gradually tend to reach the level of media and the phenomenon was faster in the 34.5 ppt treatment when all the clams died by second day itself. With respect to the osmolality values, the small clams showed a ready adjustment in the 0 and 1 ppt with minimum variations but in the 2 to 21 ppt treatments the variations till the fifth day were very high and the values stabilized on the 6th day in the 2-10 ppt treatments; beyond 13 ppt media salinity, the variations of the mantle fluid values were so drastic indicating the severe stress on the animals. This resulted in immediate total mortality on the second day itself.

The larger clams were found to maintain a proportionately higher osmotic pressure in comparison with the external medium, ranging from -0.005 osmol/kg to 0.4 osmol/kg. Beyond this, a low initial response was followed by a gradual increase. At higher salinities, the clams exhibited an immediate conformation to the media osmolality followed by heavy mortality. In clams of the smaller size group, the response to external osmotic pressure above 0.6 osmol/kg was an immediate conformation, followed by accelerated mortality rates.

The final values of mantle fluid osmotic pressure of the clams that survived after 10 days in different levels of salinities are given in Table 19.

3.11 pH Tolerance Experiments

The cumulative percentage mortality of clams at different pH levels is given in Table 20. Responses of the clams to various pH levels (11, 10.5, 10, 9.5, 9.25, 8.5, 7, 6.03, 4.5, 3.24 and 2.63) indicate that the optimal pH range of these clams is 8.5 to 4.5. 100% survival was obtained in pH of 6 and 7 while 8.5 and 4.5 pH values gave 90% survival. Moderate survival rates (60% and 40%) were seen in acidic levels of 3.24 and 2.63 respectively. Activity too was reduced at these levels. Response to highly alkaline media, ie. pH values ≥ 8.5 , showed intolerance from the part of the clams.

3.12 Correlation matrix

The results of the correlation matrix worked out for all the ecological parameters studied in relation to clam abundance are represented in Table 22 and Figs. 37 to 42.

TABLE: 20 CUMULATIVE PERCENTAGE MORTALITY OF CLAMS AT DIFFERENT pH LEVELS

pH	11	10.5	10	9.5	9.25	8.5	7	6.03	4.5	3.24	2.63
5 Hr	100	100	100	80	70	10	0	0	0	0	0
10 Hr	100	100	100	100	90	10	0	0	0	30	50
15 Hr	100	100	100	100	90	10	0	0	10	40	60

TABLE: 21 Analysis of variance

a. Turbidity:

Source	DF	MS	F
Between month	6	0.12	2.02N.S
Between station/ months	35	0.06	19.26**
	84	0.003	.

b. Temperature:

Source	DF	MS	F
Between months	6	15.05	116.93**
Between station/ months	35	0.13	24.20**
	84	0.01	

c. Water Salinity:

Source	DF	MS	F
Between months	6	559.23	22.27**
Between station/ months	35	25.11	24.75**
	84	1.01	

N.S. - Not significant at 1% & 5% level

* - Significant only at 5% level

** - Significant at 1% & 5% levels - Highly
signific.

d. Soil salinity:

Source	DF	MS	F
B.Months	6	12.41	28.63**
B.Stat/M.	35	0.43	1.86 N.S
	84	0.23	

e. Soil pH

Source	DF	MS	F
Between months	6	1.02	0.27**
Between stations/ months	35	3.79.	7.76**
	84	0.49	

f. Dissolved Oxygen:

Source	DF	MS	F
Between months	6	3.90	18.15**
Between stations/ months	35	0.21	1.33N.S.
	84	0.16	

N.S. - Not significant at 1% & 5% level

* - Significant only at 5% level

** - Significant at 1% & 5% levels - Highly signific.

g. Organic carbon

Source	DF	MS	F
Between months	6	0.78	0.12
Between stations/ month	35	6.37	6.04 **
	84	1.06	

h. Organic Nitrogen

Source	DF	MS	F
Between months	6	0.03	0.26 **
Between stations/ month	35	0.11	6.45 **
	84	0.02	

i. Organic matter

Source	DF	MS	F
Between months	66	2.35	0.12 **
Between stations/ month	35	19.05	5.94 **
	84	3.21	

N.S. - Not significant at 1% & 5% level

* - Significant only at 5% level

** - Significant at 1% & 5% levels - Highly significant

j. Sand

Source	DF	MS	F
Between months	6	62.57	0.06**
Between stations/ month	35	1014.70	4.24**
Between stations/ month	84	239.39	

k. Silt

Source	DF	MS	F
Between months	6	47.30	0.20 **
Between stations/ month	35	237.27	5.32 **
	84	44.58	

l. Clay

Source	DF	MS	F
Between months	6	58.322	0.18 **
Between stations/ month	35	330.74	2.60 *
	84	127.32	

N.S - Not significant at 1% & 5% level

* - Significant only at 5% level

** - Significant at 1% & 5% levels - Highly significant

POSITIVE CORRELATION		NEGATIVE CORRELATION	
(i)	Total abundance of clams with % sand in sediment; $r = 0.3078$	(i)	Abundance of clams with soil pH; $r = 0.2251$
(ii)	Abundance of spat with water salinity; $r = 0.2043$	(ii)	Abundance of clams with organic carbon; $r = -0.3436$
(iii)	Abundance of spat with soil salinity; $r = 0.2062$	(iii)	Abundance of clams with organic matter; $r = -0.3387$
(iv)	Abundance of large clams with % sand in sediment; $r = 0.2646$	(iv)	Abundance of clams with organic nitrogen; $r = -0.2640$
(v)	% clay with soil pH; $r = 0.2924$	(v)	Abundance of clams with % silt; $r = -0.2713$
(vi)	% clay with organic carbon; $r = 0.4894$	(vi)	Abundance of clams with % clay; $r = -0.2965$
(vii)	% clay with organic matter; $r = 0.4914$	(vii)	Abundance of spat with soil pH; $r = -0.2048$
(viii)	% clay with organic nitrogen; $r = 0.4529$	(viii)	Abundance of spat with dissolved oxygen; $r = -0.2475$
(ix)	% clay with % silt; $r = 0.5460$	(ix)	Small clams with soil pH; $r = -0.2924$
(x)	% silt with soil pH; $r = 0.3656$	(x)	Large clams with % organic carbon; $r = -0.3215$
(xi)	% silt with soil organic carbon; $r = 0.5856$	(xi)	Large clams with % organic matter; $r = -0.3171$
(xii)	% silt with soil organic matter; $r = 0.5875$	(xii)	Large clams with % organic nitrogen; $r = -0.2486$
(xiii)	% silt with soil organic nitrogen; $r = 0.5466$	(xiii)	Large clams with % silt; $r = -0.2378$
(xiv)	% organic nitrogen with soil pH; $r = 0.3275$	(xiv)	% clay with % sand; $r = -0.5829$
(xv)	% organic nitrogen with transparency; $r = 0.2072$	(xv)	% silt with % sand; $r = -0.7296$
(xvi)	% organic carbon with soil pH; $r = 0.2862$		
(xvii)	% organic carbon with soil pH; $r = 0.2830$		
(xviii)	Soil salinity with water salinity; $r = 0.6180$		
(xix)	Soil salinity with temperature; $r = 0.4281$		
(xx)	Soil salinity with transparency; $r = 2.039$		
(xxi)	Water with temperature; $r = 0.4308$		
		Critical 'r' value = 0.2; Significance at 5% level.	

Table 22 Results of correlation matrix

Fig.37a RELATIONSHIP OF NUMBER OF LARGE WITH DEPTH

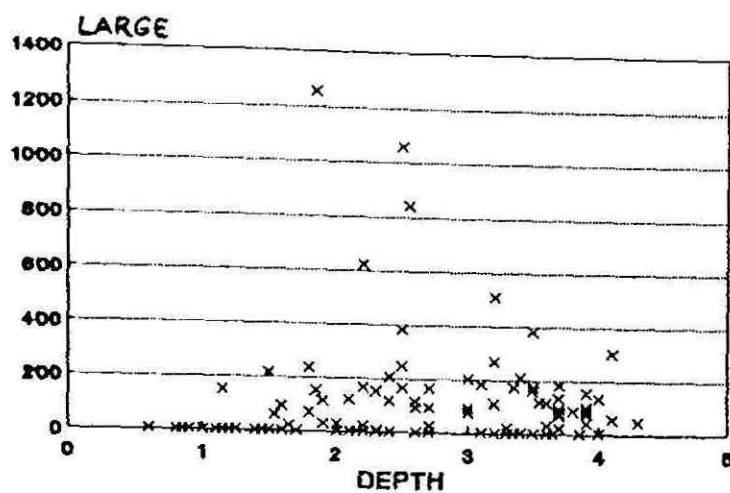


Fig.37b RELATIONSHIP OF NUMBER OF SMALL WITH DEPTH

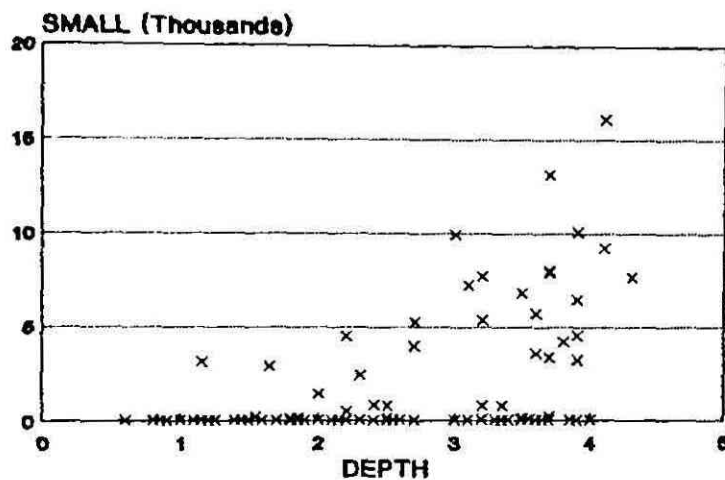


Fig.37c RELATIONSHIP OF NUMBER OF SPAT WITH DEPTH

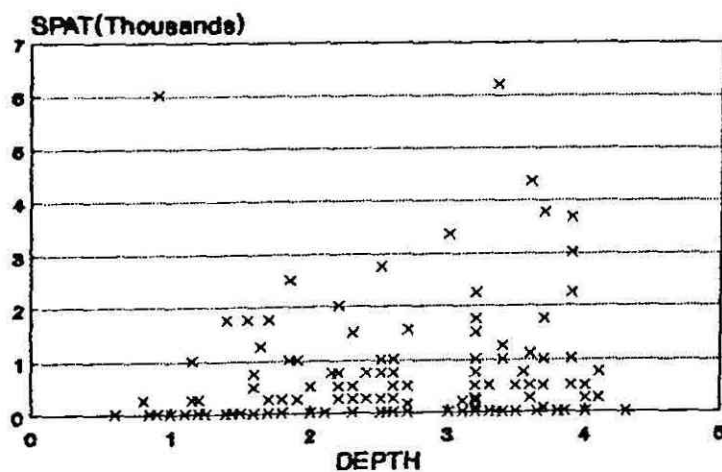


Fig.38a RELATIONSHIP OF NUMBER OF LAR6E WITH SALINITY

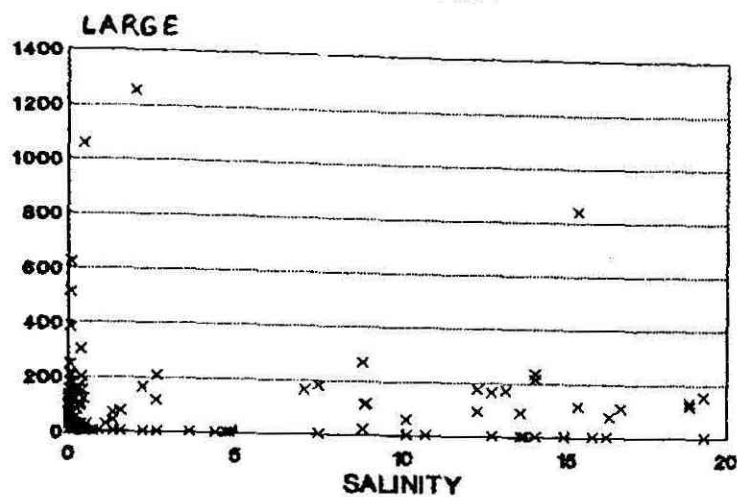


Fig.38b RELATIONSHIP OF NUMBER OF SMALL WITH SALINITY

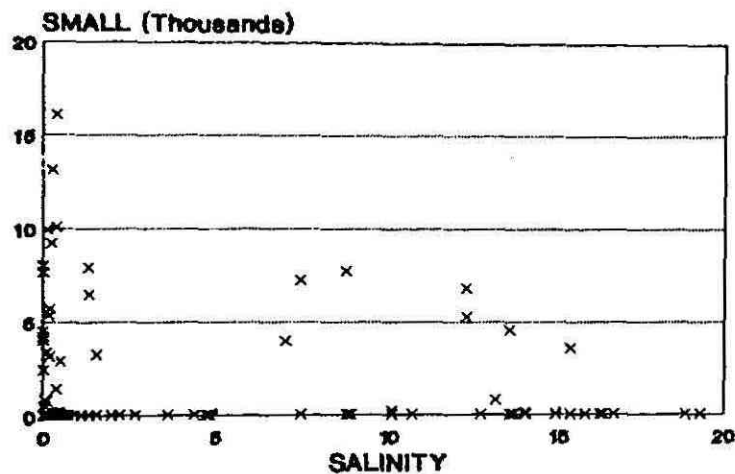


Fig.38c RELATIONSHIP OF NUMBER OF SPAT WITH SALINITY

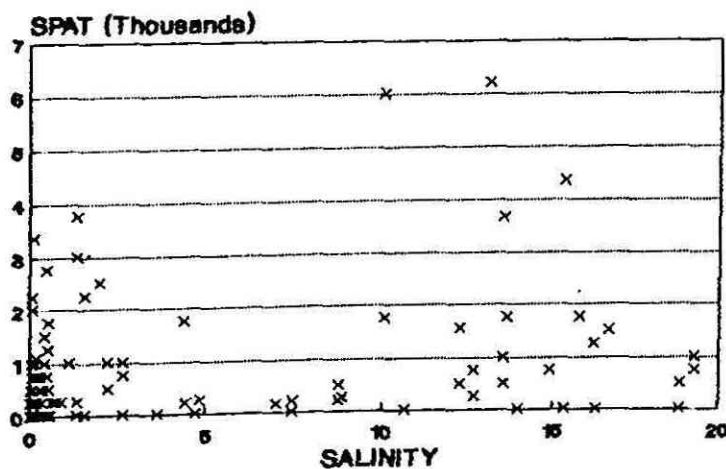


Fig.39a RELATIONSHIP OF NUMBER OF LARGE
WITH ORGANIC CARBON

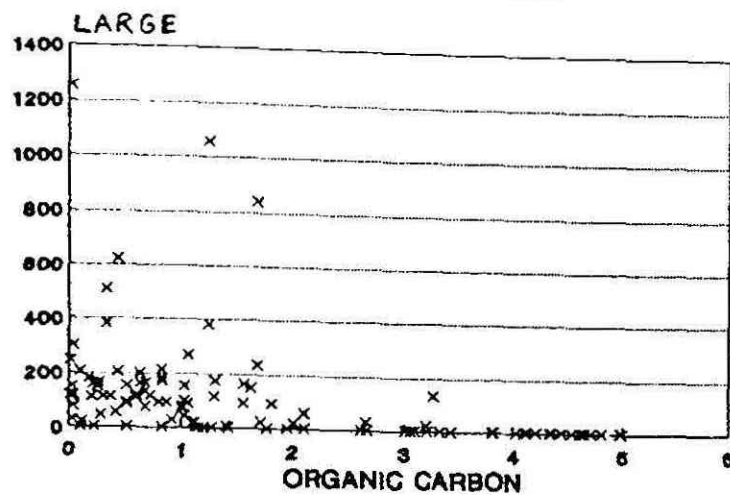


Fig.39b RELATIONSHIP OF NUMBER OF SMALL
WITH ORGANIC CARBON

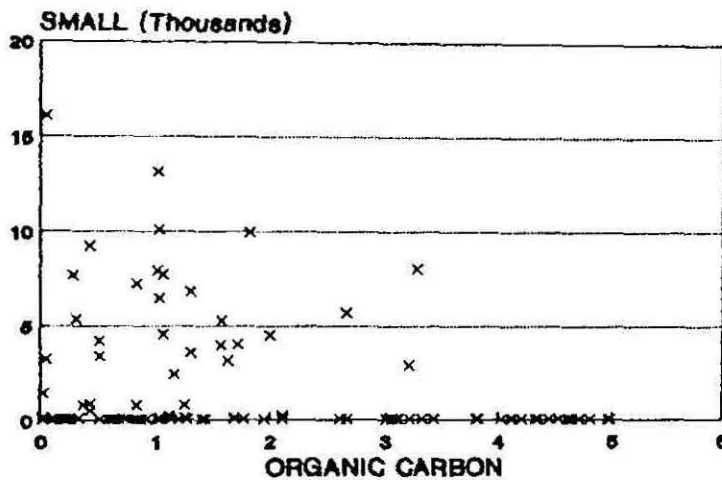


Fig.39c RELATIONSHIP OF NUMBER OF SPAT
WITH ORGANIC CARBON

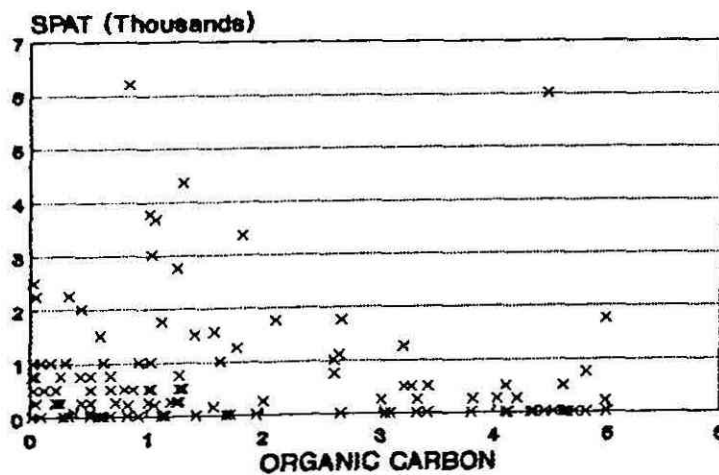


Fig.40a

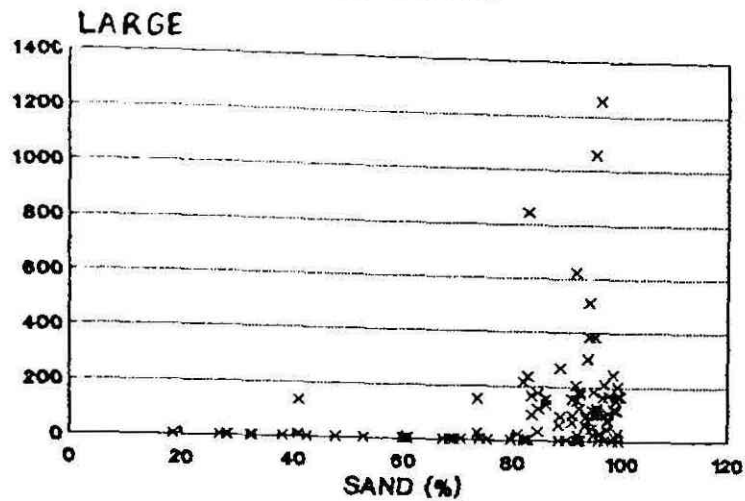
RELATIONSHIP OF NUMBER OF LARGE
WITH SAND (%)

Fig.40b

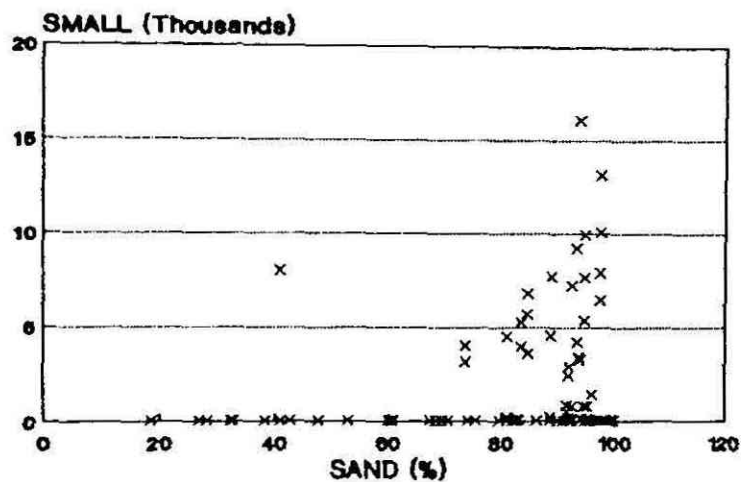
RELATIONSHIP OF NUMBER OF SMALL
WITH SAND (%)

Fig.40c

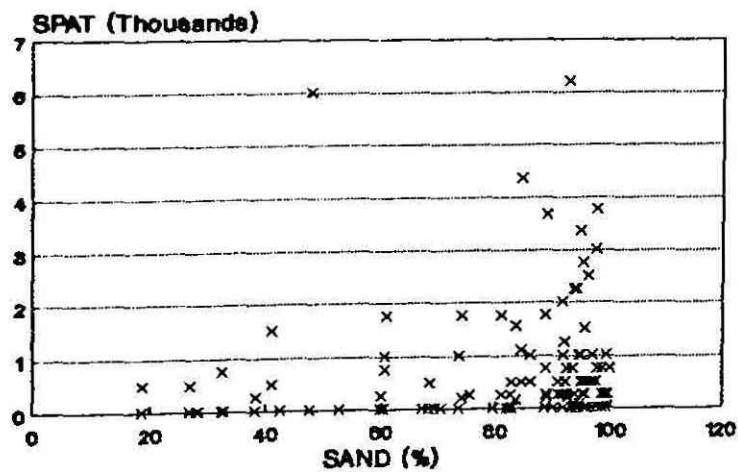
RELATIONSHIP OF NUMBER OF SPAT
WITH SAND (%)

Fig.41a RELATIONSHIP OF NUMBER OF LARGE
WITH SILT (%)

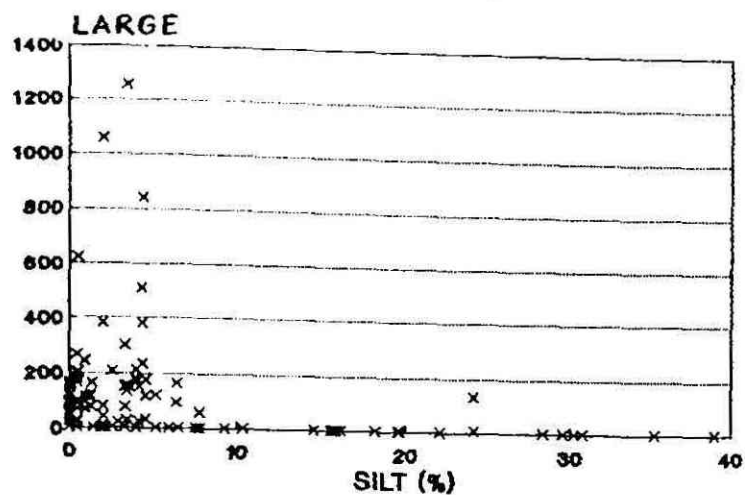


Fig.41b RELATIONSHIP OF NUMBER OF SMALL
WITH SILT (%)

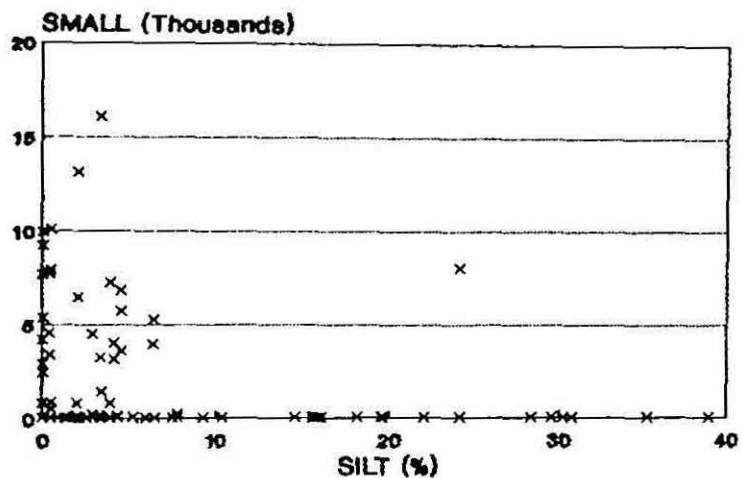


Fig.41c RELATIONSHIP OF NUMBER OF SPAT
WITH SILT (%)

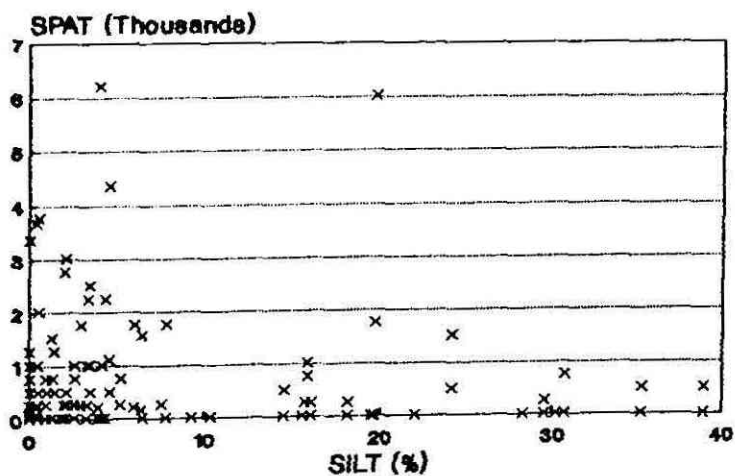


Fig.42a RELATIONSHIP OF NUMBER OF LARGE
WITH CLAY (%)

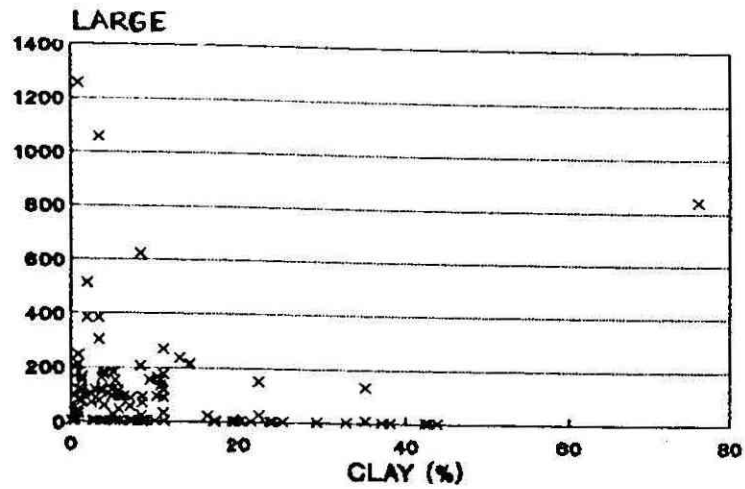


Fig.42b RELATIONSHIP OF NUMBER OF SMALL
WITH CLAY (%)

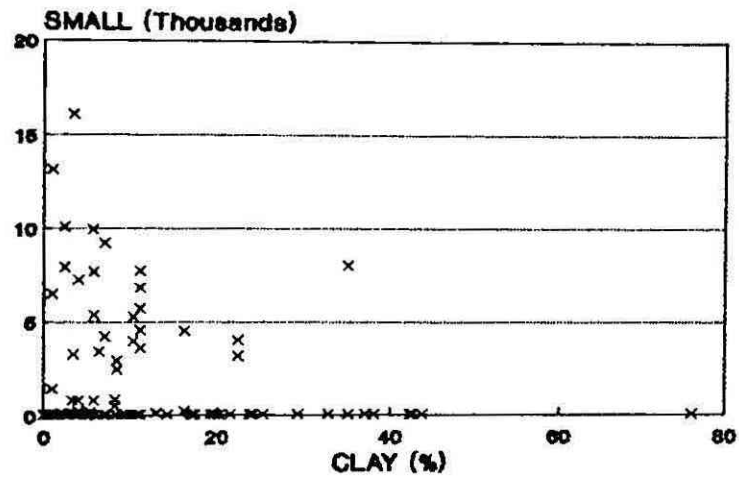
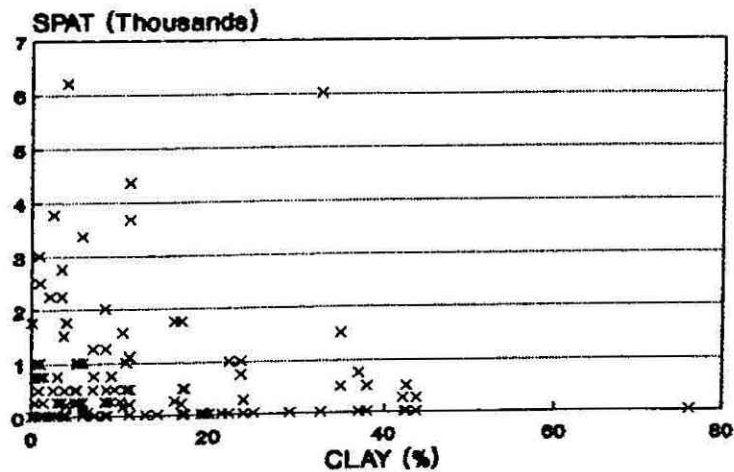


Fig.42c RELATIONSHIP OF NUMBER OF SPAT
WITH CLAY (%)



Chapter IV

IV - DISCUSSION

VARIATIONS IN CLAM ABUNDANCE IN RELATION TO ENVIRONMENTAL CONDITIONS

Depth

The studies by Verill (1874), Alee et al. (1949) and Henry and Simao (1985) indicated that depth plays a significant role in the distribution of clams. However, direct correlation between depths and animal abundance is difficult to establish due to the multifactorial operation of several parameters in complex combinations.

In the present study large clams were generally found to occur in areas lying between 1.5 and 4.3 m depth with maximum density in the 2 to 4 m deep areas, while smaller clams were predominant in the 3-4 m deep areas. Though spat fall was observed in 1.5 to 4.3 m depths, increased incidence was observed in depths between 2-4 m. The tendency of these clams to occur more or less in 2-4 m depth appears to be related to the fact that these areas, being relatively deeper, where perhaps, the wave action and tidal ingression have least effects on the sediment water interface which allows the post-set clams to remain in position at the site of settlement. Greater depths within the distributional range of the species also provide relatively stable environmental conditions. In this study, the depth in itself does not seem to be a major factor influencing the black clam distribution and abundance.

Transparency

The light permeability was found to be very poor in the study area due to heavy siltation, turbulence and land drainage. The transparency values varied significantly between stations. V. cyprinoides seems to thrive well under such conditions.

Dissolved Oxygen

This parameter did not show any significant differences between stations, indicating the general stability of dissolved oxygen values in the bottom water. The values peaked during the rainy season, probably due to the considerable turbulence associated with the freshwater discharge. The dissolved oxygen values did not show any direct correlation with the density of clams (small and large), suggesting that oxygen levels obtained during the study period may not be a limiting factor for the clam abundance. But the abundance of spat seemed to be negatively related to the oxygen levels and this may be related to factors such as the intensity of water flow, which is known to dislodge and carry the post-set clams.

Salinity

It is well known that salinity is an important ecological parameter limiting the distribution of estuarine invertebrates (Bader, 1962, Grenone, 1982).

Based on the laboratory studies conducted by Achary (1988), V. cyprinoides larvae and spat require an optimum salinity range (0-19 ppt) which is also preferred by the large size groups (Kurup et al., 1989; Joseph and Joseph, 1988 and Cheriyan, 1968). The laboratory studies on V. cyprinoides var. cochinensis for its salinity tolerance showed that 4.73-27.11 and 0.87-29.85 ppt, 4-24.5 ppt was the optimum (Nair and Shynamma, 1975) levels for the larger and smaller clams respectively.

In the present study, the salinity range of 0-19.25 ppt observed in the field, generally conforms to the optimum range indicated by the earlier authors.

The laboratory studies on salinity tolerance in the present communication showed that V. cyprinoides, in general, showed optimum survival in 0-13 ppt. However, within this range, larger clams preferred 1-5 ppt and smaller ones, 5-10 ppt.

The field observations at Station V and VI showed that the tidal influence was greater, resulting in relatively higher salinities when compared to the Stations II, III and IV. It is possible that this pattern may be prevalent during the remaining part of the year (November-March) and also the salinities may further increase in absolute value than observed during the study period. The low population density at Stations V and VI are probably related to higher salinities at these stations. The present study showed that the smaller clams (10-20 mm) have a higher optimum salinity tolerance at 5-10 ppt when compared

to the older clams (1-5 ppt). This suggests that at Station I, where low salinities prevailed for a major part of the study (1 ppt), the conditions may not be suitable for settlement and growth. However, this requires a critical study.

Organic carbon

Grenone (1982) and March and Stinemetz (1983) stated that the distribution of the benthic invertebrate animals is governed by organic carbon levels in sediment. In the present study the abundance of clams showed a negative correlation with the percentage composition of organic carbon in the sediments. In the values of organic carbon, all the stations differed significantly. The sediments constituting upto 3% organic carbon (Station II, III and V) showed high clam densities. But 3-4% supported minimal densities and greater than 4% organic carbon content invariably resulted in poor abundance. This indicates a negative relationship between organic carbon content and clam abundance. Rajamanickam and Setty (1973) reported that organic carbon has direct relationship with the clay fraction of the sediments, a fact which has been observed in this study also. And this is probably due to the predominant absorption of carbon by clay fractions (Bader, 1962). The studies by El-wakeel and Wahby (1970) and Kemp (1971) corroborated these findings. It is known that sediments having high organic carbon content support deposit feeders predominantly than filter feeders (Sanders, 1958). This may be the reason for the negative correlation obtained between the abundance of V. cyprinoides and the sediment organic carbon.

Sediment texture

Maurer et al. (1978) described well the estuarine fauna as a 'mosaic of assemblages' some of which are distinct, others amorphous, and which are associated with salinity and sediment type. With respect to the 'major benthic community' in this study i.e. V. cyprinoides, the assemblage of the same species exhibits a mosaic pattern, with increased numbers in the upstream at Stations II and III, decreased numbers in the down stream at Stations V and VI as indicated by the variance values ie. the assemblage of V. cyprinoides in the study area exhibited a patchy distribution, except for Station V, where more or less uniform density prevailed. Chapman and Brinkhurst (1981) described that benthic communities in estuaries migrate along a salinity gradient, but in the case of V. cyprinoides such migrations do not occur except during the planktonic larval phase and in the early post-set stages. The distribution of V. cyprinoides as an aggregate but patches is probably explained by the larval preferences for substratum, behaviour and mortality of post-set clams and the prevalent hydrodynamics. Littleton (1982) reported a correlation between the areas of occurrence of clams, sediment type and depth. Bourgoutzani and Zenettos (1983) concluded that distribution of molluscan fauna is related to sediment type. Cheriyan (1968) and Kurian (1967) remarked that V. cyprinoides prefers generally sand dominated substrates.

In this study, clams were found in sediments having greater than 70% sand. Their density was moderate when the sand component was greater than 80%, while maximum densities occurred in the sediment having 90% and greater sand content.

A sandy sediment provides easy retention of spat in the substrate interstices (Cuomo, 1985 and Dubilier, 1988), reduced resuspension of sediments, adequate physical support for the clams preventing them from sinking and allows free movement and burrowing. Also sandy substrates contain lower levels of organic carbon, increased interstitial water circulation and higher oxygen levels at the subsurface layers. They also provide reduced microbial action, reduced oxygen tension, neutral pH, conforming water media salinities in the soil interstices, reduced pseudofaecal output and reduced ciliary and respiratory activities.

While silt and clay composition in the sediment showed negative correlation with the clam abundance, the distribution of clams was restricted to sediments with 0-6% silt and 0-12% clay. Within these ranges, the density of both large and small clams were higher at lower levels of silt and clay. Beyond this range, clams were totally absent. The study by Chacko (1987) in V. cyprinoides var. cochinensis also showed similar substrate preferences. Sanders (1958) and Bloom et al. (1972) stated that filter feeders preferred sandy bottom while deposit feeders had preference for muddy substrates. Brett (1963), Mc Nulty et al. (1962) Anzari et al. (1977), Harkantara (1975) and Parulekar et al. (1975) made similar observations on the clam species studied by them. Parulekar et al. (op. cit) also stated that the molluscs (filter feeder) are totally absent in silt-clay bottoms. In other corbiculid clams like, Corbicula fluminea, Qi (1985) and Belanger et al. (1985) observed preferences for sediment particles greater than 0.4 mm diameter. Gottfried and Osborne (1982) inferred that C. manilensis prefers clear fine sand and occurs rarely in the silty organic sediments.

Substrate selection

Selectivity of substrates by bivalve larvae was studied by Meadows and Campbell (1972), Gray (1974), Crisp (1984), and Woodin (1986). Late pediveligers of Mulinia lateralis (bivalve) stay close to the bottom in still water (Grassle et al., 1992). Active swimming by Mercenaria mercenaria larvae tended to make them neutrally buoyant, as observed by Webb and Butman (unpublished). Factors in interstitial spaces stimulate morphogenetic changes at metamorphosis. sublethal levels and transitory levels of H_2S affect larval or adult mortality (Cuomo, 1985 and Dubilier, 1988). Differential post settlement mortality may have been an important selective agent that led to the evolution of larval preferences for specific microhabitats (Doyle, 1974 and Young and Chia, 1984).

Most settlements occur at slack water tides, than during strong flow (Gross, Werner and Eckman, 1992). Hydrodynamic processes affect the intensities of larval settlement over both large and small spatial and temporal scales (Eckman, 1983: 1987: 1990; Jackson, 1986, Wethey, 1986; Butman et al., 1988; Roughgarden, et al., 1988; Wolanski and Hamner, 1988). Thus settlement is subject to both hydrodynamic and larval behaviour controls.

In the field studies conducted with the substrate specific spat settlement sampler, the substrates comprising river sand, granite powder, Station I sediment and Panangad soil either did not yield any spat and the settlement was poor.

This may be due to the failure of the spatfall or the post-set clams did not survive long enough to be collected on the sampling days. These substrates had either too larger or too smaller grainsizes, poor or excess organic content and abnormal pH values, both acidic and alkaline than the optimal levels which appear to be the probable reasons. Good spat settlement was observed in the Station II sediment and the sand mixed with minimal proportions of manure, and this can be attributed to the optimum grain size (0.5 mm) coupled with the optimal organic content and pH values which were found to be suitable for the spat to survive.

Soil salinity and Soil pH

The sediments with greater percentages of silt and clay (finer fractions) showed the maximum retention of salts (chlorides), which obviously is related to the increased surface area and the binding properties of the particles. The pH values were in general considerably high at stations I and VI, which clearly denotes the alkaline conditions prevailing in these stations. The abundance of spat and small clams showed negative correlation with the soil pH and abundance of spat was positively correlated to the soil salinities. The laboratory experiments indicated that optimal survival was in 4.5-8 pH range and higher values of pH, beyond the range proved to be lethal. The absence or low density of clams at Station I and VI is in conformity with the laboratory studies. The increased acidic pH caused blister formation of the periostracum, while the high alkaline conditions, caused swelling of the soft parts.

Abundance and biomass

The variance values greater than mean densities obtained in this study indicate that the clams occur in irregular patches. Their densities were higher in the upstream and lower in the down stream stations. Based on the samples collected in the study area the average density of clams was estimated at 2738 nos/m² comprising 92 large, 1772 small and 874 spat.

The average biomass for all the stations in the study area worked out to 4199.465 g/m². The water spread of the study area was estimated at 60 hectares (12 km x 50 m). The total biomass in the area of study was estimated at 2520 tonnes ie. 42 t/ha.

It would be of interest to study the effect of density on growth and production of V. cyprinoides for developing strategies to augment production by thinning of the population in areas of dense clam abundance and transplantation of the clams to suitable areas. However, this aspect is beyond the scope of the present study.

Age and growth

The parameters 'K' of the von Bertalanffy's growth equation in length as fitted in the ELEFAN programme has the value 0.56 (annual) and, the asymptotic length, L_{∞} = 58 mm. The relative estimated growth increments are 24.6 mm in 1st year, 14.49 mm at the 2nd year and 8.1 mm and 4.64 mm at the

end of 3rd and 4th year respectively. It is obvious that the growth rate is reduced as the clams approach the asymptotic length. Based on the modal progression of the length-frequency data the clams measuring 10 mm attained 20 mm in 6 months. It is reasonable to assume faster growth in smaller clams (10 mm) and the 10 mm clams are probably 3-4 months old. Thus they attain 20 mm length in 9-10 months. Joseph and Joseph (1988) have given the following values for the von Bertalanffy growth equation for V. cyprinoides for the Gurupur-Nethravathi estuary in Karnataka. $L_{\infty} = 39.96$ mm, $K = 0.1289$, $t_0 = -1.74$. The authors have not indicated whether 'K' was estimated on months or yearly basis. Also the L_{∞} given at 39.16 is much on the lower side of the known growth of V. cyprinoides. As data were not presented it is difficult to comment on the growth data given by the above authors. Nair (1975) studied the growth of V. cyprinoides var. cochinensis from Cochin backwaters and observed that it attains 30 mm in first year and 41 mm in second year. The L_{∞} was estimated at 53.448 mm. Their study indicate a slightly faster growth than what was indicated in V. cyprinoides in this study. T_{max} is the longevity of the animals and according to Pauly (1983). $T_{max} = 3/K$ where K was estimated as 0.56. Therefore T_{max} for V. cyprinoides is calculated as 5.357 years. According to Taylor (1962) and Beverton (1963), oldest fish in the stock attains 95% of the asymptotic length. Based on this V. cyprinoides is expected to attain 55.1 mm length which is very close to the largest clams (54 mm) collected in the present study. In the present study on the morphometric and length-weight relationship, the regression coefficient was found to be significantly different from 1 and 3 respectively, which indicates that the rate of increase of the various parameters studied in relation to length is allometric. In several

clam populations allometric growth has been observed (Rao, 1988 and Narasimham, 1988).

The total instantaneous mortality rates were higher during the monsoon rains. Retardation of the growth in bivalves due to low salinities is well known in Indian waters (Rao, 1952; Rao *et al.*, 1964 and Mane, 1976) and a similar observation was made in the present study.

Condition index

It is well known that the condition index indicates the general well being of the clams in a given environment. In this study, the stationwise average condition index values were 12.37, 12.25, 13.35, 14.88 and 18.56 at Stations II, III, IV, V and VI respectively. This suggests that Station V and VI (downstream) offer more favourable habitat than II, III and IV (upstream).

The CI values varied significantly between the size classes. The CI values for the clams measuring 20-30 mm were generally good at all the stations during the premonsoon period, and for larger clams (> 30 mm), they were low during this period. But the clams above 30 mm showed good CI values during the post monsoon months, particularly in the downstream Stations (V and VI). And this can be attributed to the ingress of saline waters during this period at these stations. The drastic lowering of salinity in July appears to be a causative factor for the poor condition in all the size groups.

The predominance of mature clams in the smaller size groups as revealed by the gonadal smear studies during the premonsoon period seems to be a possible season for the good condition at Stations II and III.

There was maturation in clams of larger sizes in the downstream stations and they showed good CI values during the postmonsoon months. The present study clearly indicated that in V. cyprinoides spawning is protracted. This study also showed that salinity influences spawning. Several studies made in bivalves from Indian waters have indicated that both rise in salinity (Narasimham, 1985; Nagabushanam and Talikhedar, 1977; and Nagabushanam and Mane, 1975) and decrease in salinity (Hornell, 1909; Panikkar and Aiyer, 1939; Paul, 1942; Rao, 1951; Sastry, 1955 and Rao et al., 1962) influenced spawning.

Recruitment

The recruitment of benthic invertebrates is known to be highly variable in space and time (Ekman, 1967; Scheltema, 1974; Shanks, 1986; Shanks and Wright, 1987; Roughgarden et al. 1988 and Wolanski and Hamner, 1988). Sediment selectivity by settling larvae of infaunal organisms does not preclude post settlement mortality from further restricting adult distribution (Muus, 1973; Wilson, 1980; Luckenbach, 1984; Woodin, 1985; Peterson, 1985; Peterson, 1986 and Watzin, 1986). The behaviour and mortality of the freshly settled sedentary benthic invertebrates is of interest from the recruitment point of view. (Connell and Slatyer, 1977; Paine, 1979; Keough and Downes, 1982; Summerson and Peterson, 1984; Peterson, 1986 and Fairweather, 1988).

Recruitment fluctuations have important consequences for population and community structure (Yoshioka, 1982; Underwood and Denley, 1984). Variable recruitment can induce oscillations in single species population (Roughgarden, et al., 1985). Although recruitment marks the first appearance of juveniles in a population, recruitment is actually the end point of a temporal sequence that includes larval development and release (Millar, 1971) mortality and losses in plankton (Thorson, 1950) larval behaviour (Scheltema, 1974) settlement (Gaines et al., 1985) metamorphosis (Cloney, 1978) and early juvenile mortality (Young and Chia, 1984).

The present study clearly indicated the occurrence of spat in all the stations throughout the study period with few exceptions such as the absence of spat in July. The observations on the gonadal smears also indicated prolonged spawning in V. cyprinoides. Thus, the protracted brooding resulted in continuous recruitment of spat in the clam bed but the spat during the monsoon months were rarely represented in the size-frequency histograms. This may be due to mortality of the post-set clams as a result of near freshwater conditions and turbulence during the monsoon.

Based on the laboratory observation, the cumulative percentage mortalities showed the tolerance levels extending from 0-13 ppt in the black clam, V. cyprinoides. A differential response was noticed in different size groups. The older ones showed optimal survival in the 1-5 ppt range and the smaller clams showed better survival in the 5-10 ppt range. Sudden transfer of clams acclimatised in 1 ppt to greater than 17 ppt in the study, yielded immediate and

total mortality, clearly indicating the lethal levels of extreme salinity conditions. However, the clams when subjected to the 0 ppt treatment, although it proved lethal the survival of the large clams was better than the smaller clams.

The studies on clams by Gainey and Greenberg (1977) observed that mantle fluid exerts appreciable control over the osmotic concentration and osmotic pressure of the body fluids which may be attributed to valve regulation/adductor response, ionic regulation, volume regulation and osmo conformation. The present study on the osmotic concentration of mantle fluids showed the mechanism by which they react to varying salinities. A higher level of mantle fluid salinity was maintained in 0-2 ppt and 0-4 ppt treatments for large and small clams respectively, while a break was noticed in this phenomenon in 3 ppt and 5 ppt in large and small clams respectively. In large clams fluid salinity tended to be consistently lower than the media, while in smaller clams except for 5 ppt, all other high salinity treatments registered higher mantle fluid salinity values till the 13 ppt treatment. But the osmolality studies indicated that in 0-13 ppt treatment the mantle fluid osmolality levels were invariably higher. But beyond this level, immediate hypertoxicity of the fluid was noticed indicating extreme stress conditions which resulted in excessive mortality.

The relationship between species abundance and salinity in estuarine gradients was documented in a classic curve (Fig. 43) (Remane, 1934) showing that, as salinity declines from 10-5 ppt the number of marine species drops precipitously. Similarly the number of fresh water species declines markedly as salinity increases from 3-5 ppt. Thus salinity between 3-5 ppt constitute

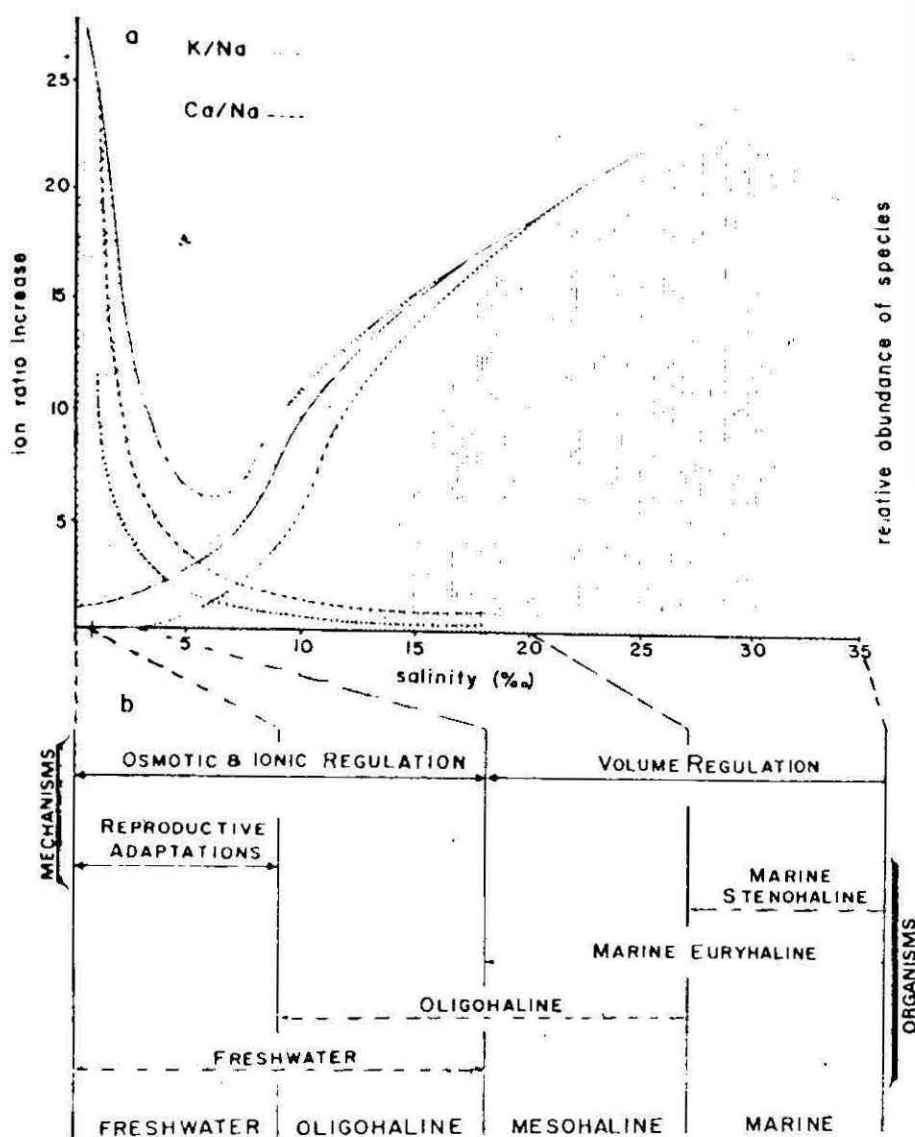


Fig. 43 Relationship between species abundance-salinity curve, ionic composition of waters of varying salinities, tolerances of molluscs living in 4 regimes within the salinity range from fresh-water to full seawater, and the adaptive mechanisms of molluscs. (a) Variation in ion ratios and relative species abundance with salinity; ion ratios $Ca:Na$ and $K:Na$ are represented as increases over their values in full seawater (after Khlebovich, 1968); species abundance curve is redrawn after Remane and Schlieper (1971); vertical hatching: marine species; white: brackish species; cross-hatching: freshwater species; each area represents the relative number of species inhabiting it. (b) Physiological basis of species abundance curve; solid arrows: mechanisms of adaptation to various salinity regimes (identified at bottom of figure); dashed arrows: categories of species and their characteristic salinity ranges in nature; volume regulation refers to cellular volume regulation; osmotic and ionic regulation refers to extracellular volume regulation; species living on both sides of the horohalinity possess both mechanisms

a barrier between marine and freshwater species; yet it is within this range that species adapted to brackish water usually occur in large numbers. The species abundance - salinity relationship has been widely confirmed in molluscs (Wells, 1961; Johnson, 1918; Davies, 1972).

The species barrier between 3-5 ppt salinity has been called, variously as the "Artenminimum" (Remane, 1934), the "Brackish water Paradox" (Khlebovich, 1969) and the "Horo-halini-cum" (Kinne, 1971; Danl (1956), eschewing species mechanism or paradoxes, suggested that, since brackish water habitats are ephemeral in geological time, the fauna of these regions have had in sufficient time to evolve and are therefore scanty}.

Gainey and Greenberg (1977) stated that the species abundance - salinity curve reflects in a complementary distribution of characteristic physiological mechanism by which animals respond to the salinity variations in particular regions of estuarine gradient. In turn these underlying mechanisms should be well represented by plots of the relationship between the internal and external osmotic pressure. On the basis of these relationships, reproductive adaptations and environmental salinity tolerances, molluscs are placed into 5 categories: "Marine Stenohaline", example: Modiolus squamosus. (Pierce, 1970), "Marine Euryhaline" eg. Pseudocyrena floridiana, "Oligohaline" eg. Polymesoda caroliniana, "Fresh water Euryhaline", eg. Corbicula manilensis and "Freshwater Stenohaline" eg. Ellipto lanceolata (Gainey and Greenberg, 1977).

The osmotic relations of the poikilosmotic molluscs are linear and parallel to (but displaced from) the isosmotic line (reviewed by Pierce, 1970). Stenohaline

and euryhaline osmoconformers differ only in the range of salinities that can be tolerated (80-100 m osm). Freshwater animals are osmoregulators in salinities approximating their natural environment (tolerate upto 3 ppt).

In truly marine animals, the internal osmotic level become even to the external media. Oligohaline species have responses characteristic of both osmoconformers (marine animals) and osmoregulators (freshwater animals). They respond to salinity changes above 3-4 ppt by osmoconformity, while below it the animals regulate like freshwater species. Therefore, at low osmotic pressures oligohaline species switch from osmotic conformity to hyperosmotic regulation, the discontinuity occurring between 3 ppt - 6 ppt (Gainey and Greenberg, 1977). Therefore the animals living in less than 119 mosm (3.9667 ppt) are ionic as well as osmotic regulators. Increased dilution increased the K:Na and Ca:Na ratio when compared to the seawater and thus leads to drastic ionic fluctuations.

Based on the classification given by Gainey and Greenberg (1977), the black clam V. cyprinoides is an oligohaline species with a wider range of salinity tolerance at 0-13 ppt in nature where it occurs in salinities lesser than 20 ppt, as revealed by the present study. Thus although 0-13 ppt has been shown as the range of tolerance in laboratory experiments the occurrence of V. cyprinoides in 0-20 ppt indicates the distributional limits in nature and distribution pattern in relation to salinity. It is also known that the adult oligohaline clam populations can tolerate freshwater conditions and survive for years, but a salinity shock is required for induced spawning, for larval development (2 ppt), embryonic development and viability (6 ppt) (Cain, 1973).

Thus the absence of spawning of V. cyprinoides in July when total freshwater conditions prevailed, is in line with the observation of Cain (1973). This is comparable to what has been observed in V. cyprinoides. Members of Corbiculidae have penetrated to freshwaters very recently in geological times (Haas, 1969; Keen and Casey, 1969). Therefore the upper salinity limit may be a physiological vestige of its relatively recent brackish water ancestry. Moreover, fresh water forms are known to have evolved from brackish water species and not the vice versa (Remane and Schlieper, 1971). Therefore V. cyprinoides can be viewed as a one way 'transient' between sea and freshwater.

The apparently low rate of speciation of oligohaline molluscs may be limited by the relatively small area of this zone in comparison with other areas. Thus upon the acquisition of reproductive mechanisms that insulate the larvae from salinity variation, oligohaline molluscs such as V. cyprinoides may tend to evolve into freshwater species with a reduced salinity tolerance and a diminished capacity for cellular volume regulation. For eg. Dreissena polymorpha was originally confined to the brackish waters in Black sea, which later migrated to freshwaters of Eastern Europe and has developed lower salinity tolerance (Remane and Schlieper, 1971). This tendency is also noticeable in V. cyprinoides which is found to occur in the farthest places from the barmouth in paddy fields and fresh water bodies of Southern Kerala.

Corbicula japonica (C. fluminalis) (0-15 ppt) and C. leana (0-5 ppt), Kado and Murata (1974); C. fluminea (0-14 ppt) Gainey and Greenberg (1974); (0-12) ppt), Evans et al. (1979) and (0-13 ppt), Morton (1985), are the other oligohaline corbiculid clams which follow the concepts given by Gainey and Greenberg (1977).

Chapter V

V - SUMMARY

Various ecological parameters dealt with, in the present study, in relation to the abundance of Villorita cyprinoides (Gray) indicated that while salinity influences the distributional limits, substrate characteristics play a significant role in determining the abundance of clams within the zone of distribution.

- A salinity regime of 0-20 ppt was found to be the distributional range of V. cyprinoides, which can be classified as an oligohaline species.
- The clams were abundant in sediments containing 1-3% organic carbon; beyond these limits, their occurrence was poor.
- Substrates comprised of more than 70% sand were found to be preferred by the clams, their distribution being limited to sediments containing 0-6% silt and 0-12% clay.
- Under favourable conditions, high densities of 16000-17000 clams/sq.m. occur.
- The wet flesh weight forms 10-12% of the shell-on weight and the dry flesh weight, 14-16% of the wet flesh weight.
- The average standing stock of V. cyprinoides in the study area was estimated at 42 t/ha.
- Maximum clam mortalities were noticed in the monsoon months.

- Poor Condition Index (CI) was noticed in smaller clams during the post-monsoon months and in larger clams during the premonsoon months, while, in general, a low CI was noticed in peak monsoon (July).
- Protracted spawning with a peak in May-June was indicated.
- Differential spawning of size classes in different salinity regimes was observed.
- Based on the von Bertalanffy Growth Equation ($L_{\infty} = 58$ mm, $K = 56$ mm, annual), the relative length was estimated at 24.6 mm, 39.09 mm, 47.19 mm and 51.83 mm in the 1st, 2nd, 3rd and 4th years respectively.
- The life span was calculated to be 5.357 years.
- The largest specimen in the collection measured 54 mm.
- Salinity tolerance limits in general, were found to be in the range of 0-13 ppt, with the larger clams showing a better survival in 1-5 ppt and smaller clams, in 5-10 ppt.
- The present study reveals that mantle fluid osmotic concentrations can be used as an index of the animal's response to varying environmental salinities.

Based on the detailed examination and enumeration of environmental parameters such as salinity and substrate characteristics preferred by V. cyprinoides, it is suggested that the information gathered would be of help in the selection of suitable culture sites for developing aquaculture of this species.

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